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PREFATORY NOTE

The American Foundation for the Blind, as a matter of course, peruses and evaluates a considerable number of articles, reports and manuscripts. Students occasionally submit their thesis or dissertation for possible publication. A Foundation staff member often encounters a research report or statistics which, in his opinion, merits wider dissemination. In some cases, the Foundation initiates or contracts for a research project and is naturally interested in publishing the findings.

Of these various papers, a few may be fortunate enough to find their way into journals not widely circulated. Others, because of their subject matter or length, may never be published.

For this reason, the Division of Research and Statistics of the American Foundation for the Blind publishes a Research Bulletin, composed both of original manuscripts and of previously published articles. The Research Bulletin appears from time to time and contains sociological, psychological and technological papers of interest primarily to research personnel, and secondarily, to those interested in the general improvement of services to the visually handicapped.

Personnel of the Division of Research and Statistics, together with other specialists on the Foundation staff, constitute an informal editorial board. Papers must be either directly or indirectly relevant to some aspect or problem of visual impairment, and must meet generally accepted research criteria. Since these are the only standards for selection, the articles published herein do not necessarily reflect the opinion of the Trustees and Staff of the American Foundation for the Blind.

We earnestly solicit contributions from all scientific fields and welcome all reaction to published articles.

M. Robert Barnett
Executive Director

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"FACIAL VISION": THE PERCEPTION OF OBSTACLES BY THE BLIND*

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INTRODUCTION

The avoidance of obstacles by the blind has long been a topic of special interest and speculation. (For an excellent review of the literature in this field see references 14; 15, pp. 93-96; and 16, pp. 49-63.) The history of the problem dates from 1749 when Diderot recorded the "amazing ability" of a blind acquaintance not only to perceive the presence of objects but also to judge accurately of their distance from him. Diderot thought his subject judged the proximity of the obstacles by the action of the air on his face - that is, by the increased sensitivity of the facial nerves and end organs (3).

Since the appearance of Diderot's account, numerous cases possessing this special ability have been reported and numerous theories have been advanced in explanation of the phenomenon. Hayes, in his excellent summary of the work in this field, lists fourteen theories which are divided into three groups according as they rest upon a sensory, a perceptual, or an occult basis (16, p. 42).

The sensory theories postulate a heightened response of some of the organs of sense, of pressure or temperature in the face, of presure in the tympanic membranes in the ears, or of audition in the increased discrimination and analysis of sound. The perceptual theories involve the interpretation of sensory cues which are derived from the action of the 'air-' or sound-waves on the skin or aural mechanisms. The occult theories explain the phenomenon in terms of magnetism, of electricity, of vibration of the ether or some other hypothetical substance, of the action of vestigial organs in the skin, and of the subconscious.

HISTORICAL BACKGROUND

As stated above, Diderot (1749) was the first to publish an ac-

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count of the ability of the blind to perceive obstacles at a distance. His explanation of the phenomenon (that is, the action of the air on his subject's face) was accepted without question by the early writers in this field. For example, Zeune (1808) claimed that the blind used their cheeks and foreheads as "feelers"; Knie (1821) regarded air pressure as the stimulus; Sergel (1867) concluded from the results of his own experience that "the distance sense" was clearest around the eyes and ears, weaker at the temples and on the forehead, still weaker on the cheeks, and almost lacking on the lips (21, 33, 44). Levy (1872) named this ability "perceptio facialis," and described some remarkable feats that he himself could perform by means of his heightened facial sensitivity to minimal pressure stimulation (26, pp. 64-68). Scherer (1874), agreeing with Sergel that the phenomenon was sensory, developed a theory relating it to the physical laws of electricity (32).

More important than these anecdotal accounts of the blind was the work of the early experimenters. The studies of Heller, around the turn of the last century, mark the beginning of the scientific research in the field. Heller wrote that "sensations of approach do not depend upon a special touch quality nor upon stimulation of a certain part of the skin." He came to this conclusion from the results of a series of experiments in which he had blind subjects approach an obstacle (a school chart, 1.65 cm wide and 1 m high, mounted on a 1-m stand) with touch or hearing eliminated. He found that the blind, under favorable conditions, perceived the presence of objects by sound at about 3 to 4 m, and by pressure at about 60 to 70 cm. Heller concluded, therefore:

> "...the perception of changes in the sound of his (the blind's) footsteps leads to careful attention for sensations of pressure in the forehead. If these characteristic sensations then arise, he is sure that an obstacle is in his path and he turns aside in good time. The sound components of the experience then serve as a signal which inhibits other processes which might prevent full attention" (17, p. 113).

At about the same time that Heller was working in Germany, some American psychologists became interested in the problem. William James (1890) suggested that the sense of obstacles might be due to pressure sensations from the tympanic membrane (18, pp. 204 ff). Dresslar (1893) tested this hypothesis in a series of carefully controlled experiments and found that the amount of pressure needed to stimulate the tympanic membrane far exceeded the amount derived from the 'air waves' aroused by a subject's approach to an obstacle (7). Dresslar than turned to the investigation of other possible clues for "facial vision." He had his subjects distinguish between different types of surfaces of an obstacle (1) when vision alone was eliminated; (2) when thermal sensations and "facial vision" were eliminated by

covering the ears, face, and neck with cloth and cardboard, leaving a hole opposite the auditory meatus; and (3) when the face was exposed but both ears stopped with cotton. Dresslar concluded, as a result of these experiments, that "the basis for judgment was due to differences in sound" (7, p. 350).

Following the work of Heller and Dresslar no serious experimental studies were made upon facial vision until the turn of the century. Javal (1903) introduced the term "sixth sense" of the blind, and supposed that it was akin to touch and aroused by ether waves (19, pp. 152-169). MacDougall (1904) repeated Dresslar's experiments with somewhat different results. He questioned the importance of audition as the essential factor for all individuals since he found that plugging the ears made no difference in judgment whereas preventing facial stimulation resulted in a lowering in correctness of response. MacDougall concluded that sound, pressure, and perhaps temperature all help in the perception of obstacles (27). Hauptvogel (1906) suggested that the "sixth sense" was due to stimulation of the ear drum by some mysterious substance in the ether (13).

The theories that the perception of obstacles by the blind was due to multiple sensory stimuli were superseded during the first two decades of this century by monosensory views. Three German investigators - Truschel, Kunz, and Krogius - maintained that the perception of obstacles by the blind was achieved by the increased sensitization of a single sense department. Beyond this generalization, however, there was little agreement among them. Each postulated that the principal role was played by a different sense department and each conducted experiments and marshaled the results to support his own hypothesis. Theory not only directed procedure but prejudiced interpretation as well. A bitter three-cornered controversy resulted which did little to clarify the problem.

Of those involved in the controversy, Truschel (1907) was the first to publish the results of his studies. He claimed that auditory stimulation was necessary for the perception of an obstacle by the blind. He was unable to decide, however, whether the organs involved were those in the cochlea or in the vestibule.

Truschel observed that, as one approaches an obstacle, the sounds of the footsteps rise steadily in pitch. The localization of stationary objects outside the path of approach was explained by him as being due to the reflection of diffuse sounds. Since these diffuse sounds did not arouse auditory perceptions, Truschel thought that the perception of the objects was due to the vestibular organs. According to him, therefore, this "X-sense," as he called it, was due to aural stimulation entirely and it was in no way dependent upon pressure or thermal stimuli (38).

Kunz (1907) was equally certain that the blind who perceive obstacles rely soley on pressure sensations. He performed a number of experiments measuring pressure sensitivity of the face, acuity of hearing, localization of sound, musical ability, and bone conduction of sound. He concluded from his results not only that the pressure sensations were the important factors in the perception but also that audition played no role (24).

Krogius (1907), using motionless subjects with movable stimuli (as Kunz did), espoused a thermal theory of the sense of obstacles although his experimental results were not decisive (22, 23).

Wolfflin (1908) followed Heller's technique and concluded that the ability of the blind to perceive obstacles was due neither to hearing, touch, or temperature, but probably had its basis in the nerves of the face, particularly the trigeminus (42).

Villey (1918) criticized Knuz and Krogius and concluded that the ears are the mechanism by which the blind avoid obstacles. There are sounds around us all the time and when there is some change in these sounds we interpret an obstacle between us and the source of the sound. Villey explained the feelings of pressure upon the forehead as an auditory illusion similar to the phantom sound localized in the middle of our heads. In 1923, Villey questioned soldiers who had been blinded by the war and found that 25 percent of them thought that they detected obstacles by the ear, 25 percent by the sense of touch, and 50 percent by a combination of the two senses. He concluded that both audition and touch play a role in the sense of obstacles and that the blind could accordingly be classified as audiles or tactiles. A combination of the two would give the maximal ability to avoid obstacles (39, pp. 101-131).

A highly fanciful explanation of the perception of obstacles by the blind was given by Romains (1924). He believed that the vestigial Ranvier corpuscles were really little eyes and that these "ocelles" were brought into function by the blind. In this book, Romains did not present the method of his experiments but gave only his results and explanation (30).

In 1929, Villey published an account of the work of Lamarque done in 1910. Lamarque was a true experimentalist. Instead of establishing a theory first and then trying to find facts to corroborate the theory, he let interpretation follow the facts. He developed techniques to supplement the commoner practices of eliminating one sense after another. Lamarque was interested in detecting the physical changes in the stimulus, something which nobody else had attempted to do. He recorded the soundwaves from a tuning fork alone and, when different obstacles were placed at varying distances between the sound source and the recorder, found that the height of the curve never changed but that the form of the curve was modified; in short, that the pitch differed whereas the loudness remained the same (25).

Dolanski (1931), in a series of experiments, moved disks of various sizes toward his observers who sat (a) with face covered, (b) wearing a flap in front of the ears, (c) wearing a cardboard mask the shape of the face, and (d) with ears plugged with cotton. He found that his subjects failed to perceive the disks under conditions (b) and (d) in which hearing was restricted. Dolanski postulated a physiological theory of the sense of obstacles. He claimed that cues from any sense department suggested danger to an individual and thus caused contraction of small muscles in the skin. The sensations from these muscles were, he believed, the basis of the perception of obstacles by the blind (6).

Mouchet (1938), independent of Villey and Dolanski, found that auditory processes were involved in the perception of obstacles. He believed, however, that subliminal auditory stimuli may play a role in this ability of the blind (28).

Not only are blind who possess the "sense of obstacles" unable to explain the basis of their performance, but, as this review shows, the investigators of the phenomenon are themselves unable to come to any agreement regarding it. Fact is entangled with theory and theory has, all too often, prejudiced interpretation of the experimental results.

PROBLEM

The present study was undertaken to resolve the contradictions between theory and experimental result. We hoped, despite (or because of) our theoretical biases,[1*] which differed greatly among us, to follow without prejudice the lead of the experimental facts and to determine the necessary and sufficient conditions for the perception of obstacles by the blind.

EXPERIMENTS

All the experiments reported here were performed in the large hall of the graduate laboratory of psychology at Cornell University. This hall is 18 ft wide, 61 ft long, and 20 ft high with beamed, center-ridged ceiling and two skylights. It has 7 doors opening into it on each side, 2 doors and a descending stairway with an open well at one end, and 1 door near a side of the opposite end. Glass-door apparatus cases and large pieces of apparatus stand along the walls. During the experiments all the doors opening into the hall were closed and all small apparatus and movable furniture were placed at the far end of the hall, well out of the way. With the

* All footnotes are designated by superscript numbers and will be found at the end of each paper.

exception of Experiments 1 and 7, all of the experiments were conducted at the end of the hall opposite the stairway with the *S*s walking toward the stairway end.

Seven experiments were conducted. The first three, Experiments 1 through 3, which were practice, exploratory, and normative, were given under conditions normal to the blind. Besides placing blindfolds over the eyes of *S*, the conditions of everyday life of the blind were practically unchanged. In the last four, Experiments 4 through 7, various controls were introduced that reduced or eliminated certain sensory cues.

General Method

In the first six experiments, Experiments 1 through 6, the blindfolded subject (*S*) was placed at varying distances in front of the obstacle and instructed to walk toward it, to stop and to raise his right arm when he first perceived the obstacle, and then, at a signal from the experimenter (*E*; Milton Cotzin acted as *E* through the experiments), to approach it as near as possible without touching it, designating when that point was reached by raising his left arm (see Figures 1, 2, and 3). These distances were recorded by *E* from a tape measure stretched tautly on the floor in *S*'s path. Distances were measured to the nearest 6-in. interval. The ratio of these distances (that is, of the 'first perception' to the 'final appraisal') was taken as the measure of *S*'s performance - for example, if one *S* first perceived the obstacle at 12 ft 6 in. and approached it to within 12 in., the ratio of his performances would be 12.5:1; if a second *S* first perceived the obstacle at 5 ft and approached it to within 6 in., his ratio would be 10:1. In these examples, one *S* excelled in the first performance, the other *S* excelled in the second. The absolute distances of the 'first perceptions' and 'final appraisals' do not permit of a ready comparison of the *S*s nor of their performances under different experimental conditions. The ratio of these distances, however, gives a single value which makes comparison easy.

In all the experiments, except those of Experiments 1 and 7, the obstacle was a 1/4-in. masonite board,[2] 4 ft wide and 4 ft, 10 in. high. This board was attached to a portable standard. Its lower edge was placed 2 ft above the floor. Its upper edge, 6 ft 10 in. above the floor, was therefore well above the elevation of *S*'s ears. In Experiments 1 and 7, the end wall of the room opposite the stairway was used as the obstacle. It is a 4-ft stone wall, hard plastered and decorated with semigloss paint, hence highly favorable for the reflection of 'air-' and sound waves. (The laboratory and equipment may be seen in Figures 1 through 12.)

The first five experiments, Experiments 1 through 5, were repeated twice: once, designated as Series A, with *S* wearing shoes

Figure 1. S *Signals with His Raised Right Arm That He Has Perceived the Wall.*

Figure 2. S *Signals with His Raised Left Arm That He Has Approached the Wall As Closely As Possible Without Touching it.*

Figure 3. S *Illustrating How Closely* S *Approached the Wall.*

and walking over the hardwood floor; and again, in the Series B, with *S* walking in his stocking feet over a soft carpet runner. These series were given in counterbalanced order: AB BA AB BA AB.

A series of experiments in this study consists of 25 successful trials (that is, trials in which *S* made his reports without coming into contact with the obstacle), or 50 consecutives failures (that is, trials in which he collided with the obstacle). Failures interspersed among successes were repeated until the number of successes reached 25.

In Experiments 1 through 6, the *S*s' eyes - blind and sighted alike - were covered with pads of cotton and a flexible leather blindfold which fitted snugly over the forehead, around the tenples, and over the checks. Thus all the *S*s were 'blind' and all had their facial areas reduced by like amounts. Except for experience, the blind *S*s had no advantage over the sighted.

Subjects

Four *S*s, two blind and two with normal vision, served throughout the study. The blind *S*s were Mr. Edward Smallwood (*ES*), an undergraduate student, and the junior author (*MS*), a graduate student in psychology. The sighted *S*s were Miss Patricia Cain (*PC*) and Mr. John W. Dallenbach (*JD*), both graduate students in psychology.

The eyes of the blind *S*s were examined by an oculist,[3] who made the following report.

ES

Age: 20 years

History: Eyes normal until 5 years of age at which time right eye was injured with a knife. Sympathetic ophthalmia followed in left eye. Right globe enucleated.

Examination: O. D. Globe removed. O. S. Phthisis bulbi; no light perception whatever.

Opinion: Destruction of right eye by injury and resulting infection requiring enucleation. Almost complete destruction of left globe following a sympathetic ophthalmia.

MS

Age: 22 years

History: Normal baby; when 18 months of age he had scarlet fever or measles, or both, and his eyes became involved. Vague history of "some strong medicine" used in eyes which was sup-

posed to have affected them. Mother thinks there was some vision for a few months. Patient cannot remember ever seeing.

Examination: O. D. Phthisis bulbi; no light perception. O. S. Phthisis bulbi; remnants of dark iris can be seen; some light perception, but no projection.

Opinion: I judge that this ocular condition results from a suppuration associated with the acute infectious disease at 18 months of age; perhaps a panophthalmitis or vitreous abscess. It is interesting to note that bright, white light is described as warmer than less intense or colored lights.

The blind *S*s possessed the ability to perceive obstacles from a distance and utilized it to a marked degree in their daily lives. Neither, however, could explain the basis of his judgment. *MS* thought that audition helped, but *ES*, on the contrary, was of the opinion that sounds hindered. The two sighted *S*s were unable, at the beginning of the study, to detect the presence of obstacles when blindfolded; they expressed grave doubt concerning their ability to learn to do so, but both were willing to try.

PRELIMINARY EXPERIMENTS

Experiment 1

Series 1 A

Because the blind *S*s were being subjected to controlled conditions and the sighted *S*s were approaching new and untried modes of experience, the first series of experiments was made as favorable as possible for the perception of obstacles. The end wall of the hall opposite the stairway, which was highly reflecting because of its size and structure, was taken as the obstacle to be perceived. *S* was, moreover, permitted to walk toward the wall over the bare hardwood floor with his shoes on and in any manner that he wished. He could click his heels on the floor, shuffle his feet, and make as little or as much noise in walking as he wished.

Procedure

After being blindfolded, *S* was led in a circuitous route around the hall by *E* for an interval of from 2 to 3 min to disorient him, and was then placed at the starting point in front of the wall at distances of 6, 12, 18, 24, 30, or 36 ft. With the exception of *MS*, a coexperimenter, none of the *S*s knew that the starting point would be fixed at multiples of 6 ft from the wall. The starting positions were selected by planned haphazard choice which guaranteed that every position was used as often as every other and without any given sequence.

Instructions

The following instructions were read to *S* at the beginning of every experimental period.

> "After you have been blindfolded, you will be led about the hall. Do not make any effort to orientate yourself. After a short interval you will be placed in a position facing the wall. When you are tapped on the back, walk forward to the wall. When you perceive the wall raise your right arm. After being tapped again, lower your arm and continue toward the wall. Approach it as closely as possible without touching it. When you have reached that point, raise your left arm.
>
> "*E* will follow close behind you and will guide you as necessary in your progress toward the wall. A touch on the right shoulder will mean to veer to the left; on your left shoulder, to the right. When both shoulders are grasped, stop, as you are about to collide with the wall."

No words were spoken during the experiments. The sounds of *S*'s footsteps (*E* wore rubber soles) were the only auditory cues available during the course of the experiments.

Results

One series of experiments (that is, 25 successful trials) was obtained from *ES*; four series were obtained from *MS*; and two series from each of the sighted *S*s.

Objective

As Table I shows, the blind *S*s needed but 25 trials to complete the first series of experiments under conditions of Series 1 A. They did not run into the wall a single time in 25 successive trials, nor did they require guidance in approaching the wall. Stepping out unhesitatingly, they walked forward in a straight line. As they both reported, their perception of the side walls enabled them to follow the path to the end wall that was equally distant from the sides. *MS* stepped heavily upon the floor. He seemed to be dependent in his performance upon auditory cues - upon the sounds of his footsteps. *ES*, on the contrary, walked as quietly as possible. Sounds, as he reported, distracted him. His judgments were dependent upon he "knew not what," but he was certain that the sounds of his footsteps were of no assistance to him.

The sighted *S*s, as was to be expected, required many more than 25 trials to achieve their first 25 successes. In their early trials, they consistently ran into the wall; but very soon, after 8 and 9 trials respectively by *JD* and *PC*, they began to succeed. *PC* required

TABLE I

RESULTS OF EXPERIMENT 1

Showing for Every *S* the Average Distance and Mean Variation in Feet of the 'First Perception' of the Wall and of Its 'Final Appraisal,' the Ratio of Those Values, and the Number of Times the *S*s Ran into the Wall. (Starting position of *S* was alone varied.)

Series		Report	*ES*	*MS*	*PC*	*JD*
A	First	first perception (p)	18.04±6.69	6.36± .64	2.12± .80	.98±.65
		final appraisal (a)	.52± .04	.54± .07	.56± .10	.56±.11
		ratio (p/a)	34.7:1	11.8:1	3.8:1	1.7:1
		S ran into wall	0 times	0 times	15 times	19 times
	Second	first perception (p)		6.08± .92	2.58±1.20	.93±.36
		final appraisal (a)		.56± .09	.68± .26	.77±.17
		ratio (p/a)		10.7:1	3.8:1	1.2:1
		S ran into wall		0 times	6 times	1 time
	Third	first perception (p)		6.15± .79		
		final appraisal (a)		.60± .16		
		ratio (p/a)		10.2:1		
		S ran into wall		1 time		
	Fourth	first perception (p)		5.64± .61		
		final appraisal (a)		.58± .13		
		ratio (p/a)		9.8:1		
		S ran into wall		2 times		
B		first perception (p)	17.88±7.17	3.46±1.36	4.70±3.38	1.18±.46
		final appraisal (a)	.62± .19	.72± .28	1.08± .51	.88±.48
		ratio (p/a)	28.8:1	4.8:1	4.3:1	1.3:1
		S ran into wall	2 times	4 times	4 times	6 times

40 trials to achieve 25 successes and *JD* required 44 trials.

Both of the sighted *S*s required guidance throughout the experiments of Series 1 A. They could not walk in a straight path but veered - particularly at the longer distances of the starting point from the wall - to the right or left. Without guidance they would have run into the side walls of the hall. In their approaches, they advanced hesitatingly, with a slow, shuffling, and noisy step.

The experiments of Series 1 A were extended with *MS* to discover whether the results of 25 trials would suffice to portray the ability of the blind *S*s. He completed 100 successes in 103

trials. Dividing his trials into groups of 25 successes, his 3 failures occurred in the third and fourth group: 1 failure in the third group and 2 in the fourth. These failures resulted from his desire to improve his position; he knew in every case that he was approaching the obstacle, but in attempting to better his record by inching up to the wall, he touched it.

His results differ little in the four series. As shown in Table I, the average distances of the 'first perceptions' and of the 'final appraisals,' as well as the ratios of those values, are all of a kind. The results of the first series are the best and of the last series the poorest, but the differences among the four series are not great. Since the first series was representative of his performance, it was decided that nothing would be gained by increasing the number of the length of the series. Therefore, only one series was conducted with *ES*, and the series in the subsequent experiments, Experiments 2 through 7, was set at 25 successful trials or 50 consecutive failures.

A second series, to provide practice as well as to determine whether 25 successful trials would suffice for them, was conducted with each of the sighted *S*s. Their performance in the second series differed little, as Table I shows, from that in the first series. With the exception of the number of their 'failures' (*PC* ran into the wall 6 times in the second series as against 15 times in the first, and *JD* ran into it once in the second series as against 19 times in the first), the results of the two series are very similar. As far as performance goes, it seemed unnecessary to increase the series-length with them.

The sighted *S*s, as illustrated by Figures 1 through 3, quickly acquired the ability to perceive obstacles while blindfolded. The practice effect with them was marked. After their first successes, their learning curves rose abruptly. (We hope in the near future to study the learning curve of this ability.) By the time they had finished the second series under conditions of Series 1 A, their ability to perceive the wall was so well developed that it seemed unnecessary to give them further practice, particularly because the remaining series in the preliminary experiments, Experiments 2 and 3, would themselves furnish all the practice necessary for the main experiments.

A comparison of the results of the *S*s (see Table I) shows that the blind *S*s are superior to the sighted in their performances as measured by the ratios of the 'first perceptions' of the wall to the 'final appraisals.' The larger ratios of the blind are due solely to their superiority over the sighted in their ability to perceive the wall. The average distance of their 'first perceptions' greatly exceeds those of the sighted *S*s, but the average distance of their 'final appraisals' does not. The blind and sighted *S*s are approximately equal in their 'final appraisals.' This relation holds whether the distances

of the 'final appraisals' are measured in gross units of 6 in. or in units of 1 in. As measured by the smaller units, their 'final appraisals' in the first series (the only series in which the distances were measured in inches[4]) averaged 3.60 ± 1.89 in. for *ES*, 4.28 ± 1.74 in. for *MS*, 4.04 ± 2.93 in. for *PC*, and 3.40 ± 2.57 in. for *JD*.

The results also show large individual differences among the *S*s; and the differences between the blind are greater than those between the sighted *S*s. The ratio of performance of *ES* is, for example, about three times as large as that of *MS*, while the ratio of *PC* is only a little over twice that of *JD*.

ES possessed a very keen "sense of obstacles." The average distance of his 'first perceptions' is 18.04 ± 6.69 ft. This value does not, however, represent his true ability. Both the average and mean variation (mv) are artifacts of the experimental conditions. He always perceived the wall immediately upon being led to the starting points at 6, 12, and 18 ft, and in most trials at 24 ft. Because the distance of the 'first perceptions' was, in those instances, counted as the distance of the starting points, his average was lowered and the variability of his judgments was increased. When his results were computed from trials starting at points beyond 24 ft, that is, at 30 and 36 ft, the average of his 'first perceptions' was 25.62 ± 3.56 ft. Those values represent a truer picture of his ability to perceive obstacles at a distance than those given in Table I.[5]

Walking the *S*s around the hall before every trial to disorient them was highly successful with the sighted *S*s; they never had an idea of the point from which they were started. It failed, however, in the case of the blind *S*s. They could both determine, with a small margin of error, their approximate starting positions. They based their judgments upon irregularities in the floor, with which they soon became familiar, and upon their perception of obstacles (apparatus and apparatus cases) that stood at the sides of the hall.

S's Comments

The *S*s were encouraged, during the course of the experiments and at their completion, to describe the bases of their judgments. However, none was able to do so. The blind *S*s merely reiterated the biases that they brought to the experiment. *ES* was still of the opinion that his judgments were based on cutaneous cues which centered in his forehead. "The wall," as he reported, "casts a shadow on my forehead which is felt and which becomes more intense the closer I get to it." *MS*, similarly, still held to his auditory theory. He "listened," as he reported, for the reflected sounds. Neither of the sighted *S*s was able to offer

any explanation. "I don't know," *JD* reported, "whether I hear or feel it; it just suddenly appears to be there."

Summary

The results of Series 1 A may be summarized as follows.

1. Sighted *S*s, who are blindfolded, are able to learn to perceive obstacles at a distance.

2. They, as well as the blind *S*s, are able to differentiate between the 'first perception' of the wall and its 'final appraisal.'

3. The blind *S*s are superior to the sighted in the distance at which they are able first to perceive the wall.

4. All the *S*s show approximately equal ability in their 'final appraisal' of the wall.

5. The performances of the blind *S*s are on the whole less variable (as indicated by the size of the mv) than those of the sighted *S*s.

6. None of the *S*s has insight into the basis of his judgments.

7. The sighted *S*s alone were disoriented by being led about the hall before every trial.

Series 1 B

Immediately following the conclusion of the experiments of Series 1 A, the experiments of Series 1 B were conducted.

Procedure

The procedure in Series 1 B was, with one exception, identical with that of Series 1 A. The single exception was that *S* walked in his stocking feet upon a long, 30-in. wide carpet runner that extended unbrokenly from a distance of 40 ft to the wall.

The carpet not only deadened the sounds of *S*'s footsteps, but it also served as a guiding path from the starting point to the wall. *S* was immediately aware when he stepped off the carpet and could immediately return to it. The necessity of *E*'s guiding the sighted *S*s to keep them from veering into the side walls was therefore eliminated.

The section regarding guidance was omitted from the instruc-

tions; otherwise the procedure was unchanged.

Results

Objective

The results are shown in Table I. Considered as a group, performance was diminished. Not only did all the *S*s run into the wall in this series (*ES* ran into it 2 times; *MS*, 4 times; *PC*, 4 times; and *JD*, 6 times), but the mv of all the averages of all the *S*s is greater. The decrement of performance in this series is particularly evident in the results of the blind *S*s. Their ratios of performance are markedly decreased. The averages of the 'first perceptions' are not only lower, but the averages of their 'final appraisals' are increased. The reduction of sound seemed in their cases to affect performance.

Except for a large increase in the size of the mv, the results of the sighted *S*s are slightly better in this series than in Series 1 A. The improvement in their cases is doubtlessly due to the effect of practice. They were at the beginning of the learning curve in Series 1 A; their practice in that series more than made up in Series 1 B for the loss of the sensory cues that resulted from the deadening of their footsteps.

The blind *S*s were superior to the sighted in the average distance of their 'final appraisals' as well as in the average distance of their 'first perceptions.'

The attempt to disorient the *S*s before placing tham at the starting positions failed again in this series with the blind *S*s. While their perception of obstacles at the sides of the room was the same as before, their perception of irregularities in the floor was rendered clearer by reason of their stocking feet. They knew in every trial approximately the position from which they were starting.

S's *Comments*

As in Series 1 A, none of the *S*s was able to explain the basis of his judgments. *ES*, not knowing that his performances had been adversely affected, was pleased with the new conditions. The distracting noises of his shoes on the hardwood floor were eliminated. He should, on the basis of his theory, have done better, not worse, as he actually did. His theory, in the light of the results, seems to be inadequate. *MS* was surprised to discover that he walked to the wall in this series of experiments with his face turned to one side. He could do better, as he reported, with his head in that position than with it held straight forward. Whether he turned his head to aid in hearing or to increase his facial sensation, he was unable to decide, but, true to his bias, he was inclined to

believe that it was the former. *PC* shuffled her feet vigorously "to make some noise," but beyond that she had no explanation to offer. *JD* reported that the experiments were harder in this series because "there were no sounds, hence no sensations upon which to base my judgments." As the results show, however, he did better in this series than he did in the first. His position in the learning curve, as pointed out above, may explain the slight descrepancy between his report and performance.

Experiment 2

The end wall of the hall had served its purpose well in the first experiment. The sighted *S*s had learned to perceive obstacles by means of it and the blind *S*s had become accustomed to experimental controls under conditions that were approximately normal to them.

Since the blind *S*s could not be disoriented in the experimental hall, the 'wall' (that is, the obstacle to be perceived) had to be capable of being moved to different positions. The masonite screen, described above, was therefore used as a substitute. In order that *S* would not confuse the screen with the wall, his starting position was placed at a fixed point near the wall and the screen was placed in the center of the hall at distances of 6, 12, 18, 24, and 30 ft from him. These distances were selected as before in planned haphazard order which guaranteed that every position should be used equally often and without repeated sequences.

The Series

As in Experiment 1, two series of experiments, A and B, were conducted. In Series 2 A, *S* wore shoes and walked on the hardwood floor in the path between two carpet runners which were laid paralle 2 ft apart and extended 40 ft into the hall. Since *S* knew when he stepped out of the path onto the carpet and could immediately make the necessary correction, *E* did not have to guide him. The screen was placed across the path with its legs upon the carpet runners.

In Series 2 B, *S* walked in his stocking feet on one of the carpet runners. In this series the legs of the screen, which were 4 ft apart, were set to straddle the carpet runner (see Figures 7 through 9). This brought the center of the screen over the center of the runner. It also left unchanged the looseness of the carpet in the immediate vicinity of the obstacle. When the obstacle was placed on the runner, as was done in investigatory experiments, *MS*, who was the trial horse, was able to obtain cues regarding its nearness from the increased tautness of the carpet in the immediate vicinity of the obstacle.

Procedure

After *S* was blindfolded, and after every trial in both series, he was brought to an anteroom. While he was there, *E* placed the screen in its proper position and then led *S* to the starting point. Consequently, *S* had no extrinsic knowledge, as the blind *S*s had in Experiment 1, regarding the position of the obstacle. At a signal, a tap on the back (no words were spoken after *S* had been brought into the experimental room), *S* walked toward the obstacle, designating his 'first perception' and 'final appraisal' as before by raising his right and left arms. As in Experiment 1, *S* was permitted to walk to the wall in any manner that he wished.

The instructions, read at the beginning of the experimental period, were the same as in Experiment 1 except for the omission of the section regarding guidance.

In accordance with the counterbalanced order of conducting the experiments with shoes on and shoes off, Series 2 B was conducted before Series 2 A.

Results

Objective

The results of the two series, Series 2 A and 2 B, are given Table II. As this table shows, all the *S*s were able, despite

TABLE II

RESULTS OF EXPERIMENT 2

Showing for Every *S* the Average Distance and Mean Variation in Feet of the 'First Perception' of the Masonite Screen and of Its 'Final Appraisal,' the Ratio of Those Values, and the Number of Times the *S*s Ran into the Screen. (*S* started from a fixed point; the position of screen was alone varied.)

Series	Report	*ES*	*MS*	*PC*	*JD*
A	first perception (p)	15.60±5.54	3.70±1.50	3.22±1.29	2.98±2.30
	final appraisal (a)	.58± .13	.74± .27	.62± .20	.94± .70
	ratio (p/a)	26.9:1	5.0:1	5.2:1	3.2:1
	S ran into screen	0 times	1 time	3 times	7 times
B	first perception (p)	13.62±7.72	4.88±3.25	4.54±2.74	1.50± .68
	final appraisal (a)	1.10± .80	2.86±3.19	1.20± .71	.66± .24
	ratio (p/a)	12.4:1	1.7:1	3.8:1	2.3:1
	S ran into screen	4 times	4 times	3 times	15 times

the decreased size of the obstacle and the increased rigor of the experimental conditions, to perceive and to approach the masonite screen. Their performances, measured by the ratios of the averages of the 'first perceptions' and the 'final appraisals,' are better in Series 2 A than in Series 2 B. Shoes on the hardwood floor yielded larger ratios than stocking feet on the carpet runner. Sound again seemed to be a positive aid to the *S*s. This conclusion is also confirmed by the fact that the *S*s collided with the screen more times in Series 2 B than in Series 2 A.

ES, whose performances were, as in Experiment 1, greatly superior to those of the other *S*s, was again able to perceive the obstacle from the starting position when it was at the shorter distances - that is, 6, 12, and 18 ft. The large mv of the averages of his 'first perceptions' are in great part due to that fact. As computed from the trials in which the obstacle had been placed 24 and 30 ft from the starting position, the averages of his 'first perceptions' were 23.20 ± 3.41 ft in Series 2 A, and 21.42 ± 4.84 ft in Series 2 B.

PC's ratios of performance were second to *ES*'s in both series of this experiment. The averages of her 'first perceptions' were slightly poorer than *MS*'s, but she greatly surpassed him in the nearness of her 'final appraisals.' *MS*'s ratio in Series 2 B was also exceeded by *JD*'s. The rank order of the *S*s in the series was as follows.

Rank Order: Series 2 A

S	Ratio
ES	26.9:1
PC	5.2:1
MS	5.0:1
JD	3.2:1

Rank Order: Series 2 B

S	Ratio
ES	12.4:1
PC	3.8:1
JD	2.3:1
MS	1.7:1

For the first, and, though we anticipate the results of the later experiments, we may also add for the only time, the sighted *S*s surpass the blind.

S'*s Comments*

To their earlier reports regarding the basis of their judgments,

the blind *S*s added nothing in this experiment. The sighted *S*s, however, did contribute several new observations. *PC* reported during the trials of Series 2 B that "there is some kind of a facial pressure, but I don't know what it is." *JD*, on the contrary, reported that "facial pressures which I thought for a while I was getting are, as I am now convinced, matters of imagination. I couldn't perceive the obstacle if I didn't scrape my feet. I listen for changes in the sounds from my feet."

Comparison of results of Experiments 1 and 2

A comparison of the results of Experiments 1 and 2 reveals that the blind *S*s did poorer and the sighted *S*s better in Experiment 2. The blind *S*s were adversely affected by the decrease in the size of the obstacle and the increased rigor of the experimental conditions. The sighted *S*s were probably similarly affected, but, because they were on the rising curve of practice, the improvement due to learning more than made up for the increased difficulty of the new conditions.

Experiment 3

The *S*s were undoubtedly aided in their performances in Experiment 2 by being started from a fixed position at the end of the hall. They did not know, to be sure, where the obstacle had been placed, but they did know the position from which they started. Whether this was helpful cannot be said from the results at hand, but in Experiment 3 even that bit of information was denied the *S*s.

Procedure

With but three exceptions, the procedure of Experiment 3 was the same as that used in Experiment 2. The first exception concerned the starting position. Instead of starting from a single fixed position, the *S*s were started from one of five. *S*'s starting position, as well as the position of the obstacle, was changed at every trial. The starting positions, which were 0, 3, 6, 9, and 12 ft from the end wall of the hall, were varied in planned haphazard order. After determining the starting position, *E* placed the screen 6, 12, 18, 24, or 30 ft from it.

The second change involved the introduction of *Vexirfehler* - that is, 'false' or check experiments. In a few of the trials with every *S*, the screen was not placed in the path but was removed to the far end and placed against the side wall of the hall. *S* was then led from the anteroom to the determined starting position as in all the other trials. He did not know that these check experiments would be given.

The third change consisted in doubling the thickness of the

carpet runner in Series 3 B. One of the runners was placed over the other in an effort to deaden further the sounds of *S*'s footsteps.

Series

Two series of experiments were conducted: Series 3 A with shoes on and Series 3 B with shoes off. Series 3 A was conducted first.

Results

Objective

The performance of the *S*s in Experiment 3 is illustrated by Figures 4 and 5. All the *S*s, as Table III shows, were able in both series,

Figure 4. S *Signals with His Raised Right Arm That He Has Perceived the Movable Masonite Screen.*

Figure 5. S *Signals with His Raised Left Arm That He Has Approached the Screen As Closely As Possible Without Touching it.*

TABLE III

RESULTS OF EXPERIMENT 3

Showing for Every *S* the Average Distance and Mean Variation in Feet of the 'First Perception' of the Masonite Screen and of Its 'Final Appraisal,' the Ratio of Those Values, and the Number of Times the *S*s Ran into the Screen. (Position of *S* and of the screen were both varied.)

Series	Report	*ES*	*MS*	*PC*	*JD*
A	first perception (p)	17.08±6.96	3.98±1.18	3.34±2.13	3.20±1.70
	final appraisal (a)	.50± .00	.58± .14	.84± .34	.66± .27
	ratio (p/a)	34.2:1	6.9:1	4.0:1	4.8:1
	S ran into Screen	0 times	3 times	1 time	1 time
B	first perception (p)	8.16±5.58	2.38±1.03	1.08± .36	1.72±1.33
	final appraisal (a)	.50± .00	.54± .07	.50± .00	.52± .04
	ratio (p/a)	16.3:1	4.4:1	2.1:1	3.3:1
	S ran into Screen	1 time	3 times	1 time	1 time

despite the increased rigor of the experimental conditions, to perceive the obstacle and to approach closely to it. Except for *MS* who ran into the screen 3 times in each series, the other *S*s ran into it fewer times (0 and 1 time in the A- and B-series respectively by *ES*, 1 and 1 time respectively by both the sighted *S*s) than in either of the preceding experiments.

The blind *S*s were again superior to the sighted in both series of the experiment. The ratios of performance in order of merit are:

Rank Order: Series 3 A

S	Ratio
ES	34.2:1
MS	6.9:1
JD	4.8:1
PC	4.0:1

Rank Order: Series 3 B

S	Ratio
ES	16.3:1
MS	4.4:1
JD	3.3:1
PC	2.1:1

The ratios of *ES*, which are again much greater than those of

any of the other *S*s, were still not representative of his true ability. He immediately perceived the screen at every trial in Series 3 A when it was placed at the shorter distances (6 and 12 ft) from the starting position, and in Series 3 B at every trial when it was placed at the shortest distance. His 'first perceptions' averaged 23.6 ± 3.2 ft when the two longer obstacle distances alone were used in Series 3 A for the computation, and 9.13 ± 4.08 in Series 3 B when the shortest obstacle distance (6 ft) was omitted.

The performances of all the *S*s suffered a marked decrement in Series 3 B. The double thickness of the carpet runner, which reduced further the sounds of *S*'s footsteps, was effective for all the *S*s. The relative as well as the absolute differences was greatest, however, for *ES* who made his judgments, as he erroneously thought, without the aid of sound!

None of the *S*s fell victim to the 'false' or check experiments - that is, none of them 'perceived' the obstacle when it was not there. In the instances in which the check experiments were conducted, they walked down the path (between the carpet runners in Series 3 A, and on the superimposed runners in Series 3 B) until they approached its end.[6] At that point they were stopped by *E* who conducted them, without comment or explanation, back to the anteroom. Whatever role imagination may play in this perception, it was not sufficient to cause our *S*s to report an obstacle that was not present.

S'*s Comments*

The subjects' reports, given during and after the experiment, added considerable that was new. *MS* merely reiterated his dependency upon sound, but the other *S*s returned some pertinent observations. *ES* "was amazed" during the trials in Series 3 B that he seemed "to be on top of the screen" when he first perceived it. He reported that the "pressure sensations do not feel anywhere nearly as strong as before," that he was not sure that he felt the screen at the greater distances, and that he was "less certain that audition did not play a role in his judgments," because he frequently found himself "listening" during his progress toward the obstacle.

PC stated that she did better when she scraped her feet and that she was always less certain about her 'first perceptions' than her 'final appraisals.' Her observations were borne out by her behavior. She shuffled and scraped her feet continuously in walking toward the obstacle, and the mv of the average of her 'final appraisals' was smaller, both relatively and absolutely, in both series in this experiment than the mv of the average of her 'first perceptions.' The latter were materially aided by the fact that her breath, as she reported, "comes back in my face when I get close to the screen." *JD*, whose 'first perceptions'

were also more difficult than his 'final appraisals,' made independently a similar observation during Series 3 B regarding his breath. He reported, "When I come close to the screen, my breath seems to be reflected back into my face and I hear as well as feel it." His dependency on sound for his 'first perceptions' was also indicated, as in *PC*'s case, by his behavior during the trials. He shuffled and scraped his feet throughout his progress toward the screen.

Summary and Discussion of the Preliminary Experiments

The preliminary experiments, as stated above, were practice, exploratory, and normative. They were conducted to define or to set our problems rather than to solve them. They started with conditions that were highly favorable to the blind's perception of obstacles and passed to conditions that were susceptible of more rigorous control.

In Experiment 1, *S* walked toward the end wall of the large experimental hall from varying starting points - the obstacle was stationary, but *S*'s starting position was varied. In Experiment 2, *S* walked from a fixed position at the wall to a masonite screen that was placed down the hall at varying distances from that point - the position of the obstacle was varied, but *S*'s starting position was fixed. In Experiment 3, *S*, starting from varying positions, walked down the hall to the screen that was placed at varying distances from his starting position - the position of the obstacle and of *S*'s starting point were both varied.

In Experiment 1, *S* was walked about the hall to disorient him so he would not know the position from which he was started at the various trials. This precautionary measure was only partially successful. It worked out in the cases of the sighted *S*s but failed with the blind. A more efficacious method of achieving that end was used in Experiments 2 and 3. *S* was placed in an anteroom while the position of the screen was changed. Under that method, none of the *S*s had any knowledge of the screen's location prior to his approach and perception of it.

Every one of the three experiments was performed twice. Once, as Series A, with *S* wearing shoes and walking on the hardwood floor; and a second time, as Series B, with *S* in stocking feet walking on a carpet runner, which was of double thickness in Experiment 3.

From these experiments, the following information was obtained.

1. Our blind *S*s possessed the ability to perceive ob-

stacles at a distance in a high degree. They brought to the study the experience of a lifetime, as well as the habits and "tricks of the trade." Neither was able to explain his ability, but each favored one of the classical theories, which fortunately for the study rested on different sensory bases. One of them thought his judgments were based on hearing, the other that they were matters of facial pressure.

2. Neither of our sighted *S*s possessed the ability, at the outset of the study, to perceive obstacles at a distance while blindfolded, but they soon learned to do so. Under the highly favorable conditions of Series 1 A, they rapidly acquired the ability. Their learning seemed to be insightful because, after their first successes, which followed an initial run of failures, they seldom collided with the obstacle.

3. Both the blind and the sighted *S*s were able to differentiate between the 'first perception' of the obstacle and the near approach to it - that is, its 'final appraisal.'

4. The distances of the 'first perceptions' of the blind *S*s were greater than those of the sighted *S*s. Incidentally, *ES*, the blind *S* who thought he based his judgments on pressures on his forehead, was greatly superior to all the other *S*s.

5. In their 'final appraisals,' the sighted *S*s did approximately as well as the blind. In Experiment 1, in which the sighted *S*s were learning to perceive obstacles while blindfolded, the blind *S*s approached the wall more closely on the average than the sighted *S*s. In the later experiments, however, the blind were not uniformly superior. In Experiment 2, Series A, *PC* approached the masonite screen more closely then *MS*, and in Series B, *JD* approached it more closely than either of the blind *S*s, and *PC* more closely again than *MS*. In Experiment 3, the blind surpassed the sighted *S*s in Series A, but in Series B both of the sighted *S*s surpassed *MS* and one of them, *PC*, equaled *ES*.

6. The ratio (p/a) of the distance of the 'first perceptions' (p) to the distance of the 'final appraisals' (a) was proposed and used as a measure of the *S*s' performances. This value takes into account the dual nature of *S*'s task and it has the advantage of rendering easy the comparison of the *S*s and of the experimental conditions under which they served. If used judiciously, with due regard to the data from which it was computed, this value may be of utility in this field of research.

7. With ratios of performances as the measuring stick, we find that with one exception the *S*s (*PC* in Experiment 1) did better in the A-series of experiments in which they walked on the hardwood floor than in the B-series in which they walked on carpet runners. These results suggest that sound may play a role in their performance.

An analysis of the data from which the ratios of performance were computed reveals, however, that the decrement in performance in the B-series was due chiefly to decreases in the distance of their 'first perceptions.' For instance, the average distances of the 'first perceptions' are larger (that is, superior) in the A- than in the B-series for two of the *S*s (both of the blind) in Experiment 1, for two (one blind and one sighted) in Experiment 2, and for all of the *S*s in Experiment 3; while the average distances of the 'final appraisals' are smaller (that is, superior) in the A- than in the B-series for all the *S*s in Experiment 1, for three (both of the blind and one of the sighted) in Experiment 2, and for none of the *S*s in Experiment 3. From these results it is clear that sound plays a greater role in the *S*s' 'first perceptions' than in their 'final appraisals.' Indeed, from the results of Experiment 3 it is to be doubted whether sound played a helpful role in determining the nearness of the 'final appraisals' of any of the *S*s.

8. The results of all the *S*s, except *PC*, show no relationship between the distances of their 'first perceptions' and 'final appraisals.'[7] A 'good' 'first perception' (that is, one at a greater distance than usual) did not guarantee a 'good' 'final appraisal' (that is, one at a smaller distance than usual); nor a 'poor' 'first perception' (that is, one less than usual), a 'poor' 'final appraisal' (that is, one greater than usual). The distances of their judgments varied neither concomitantly nor inversely but independently - a relationship which suggests that the paired judgments ('first perceptions' and 'final appraisals') were based upon different and independently varying factors.

PC's results, on the other hand, stand in opposition to those of the other *S*s. Her paired judgments are correlated and the relationship is an inverse one. Her good 'first perceptions' are paired with her poor 'final appraisals,' and contrariwise, the poor 'first perceptions' are paired with her good 'final appraisals.' For her, at least, the paired judgments seem to be based upon different and negatively related factors which vary dependently.

The independent variability of the 'first perceptions' and the 'final appraisals' seems to indicate that they rest upon different sensory bases; at least that is a possibility that must not be neglected.

9. A comparison of the results of the different experiments reveals that the blind *S*s' performances, as measured by the ratio p/a, declined sharply in both the A- and the B-series when they passed from Experiment 1, in which conditions were similar to their everyday life, to the controlled and more artificial conditions of Experiment 2. Although the rigor of the experimental conditions was further increased in Experiment 3, both of the blind

*S*s were able to adjust to the changes in part (*ES* in Series 3 A and *MS* in Series 3 B) and to approximate their performances in Experiment 1.

The sighted *S*s, on the contrary, tended to improve their performances throughout the course of the experiments: *JD* in both the A- and B-series and *PC* in the A-series. Their improvements were undoubtedly due to the effects of practice.

The situation in Experiment 1 was very different for the sighted and the blind *S*s. To the sighted, the situation was novel and strange; but not to the blind *S*s. To them it was but a repetition of their daily experiences. The shift from the conditions of Experiment 1 to those of Experiment 2 was a real change for the blind *S*s - and relatively a greater change for them than for the sighted *S*s because of that fact. To the sighted *S*s, the shift to the more rigorous experimental conditions of Experiment 2 were relatively slight compared to the highly complex situation that they were called upon to meet in Experiment 1. The shift, to be sure, increased the difficulty of their problem, but the increment was not of the same proportions to them as to the blind *S*s.

10. Check or 'false' experiments, in which the masonite screen was, unknown to *S*, omitted from his path, were introduced in Experiment 3. Except for that omission, the procedure in these trials was identical with that of the regular series. None of the *S*s reported the perception of the screen in the 'check' trials. It is certain, therefore, that the basis of the perception of obstacles, whatever it may be, is so compulsory that it cannot, under our conditions at least, be replaced by imaginal components.

11. The comments or reports, given by the *S*s during and after the various series of experiments, contributed little on the whole to our knowledge of the "obstacle sense." The procedures used in the experiments were not set for an introspective study. Reports were taken, and encouraged, but they were not systematically called for. Nevertheless, some insight into our problem was obtained from the *S*s' observations. *ES*, who thought at the beginning of the study that his "obstacle sense" was based entirely upon cutaneous pressures localized in his forehead, that sound played no role, was less certain of that contention at the conclusion of the preliminary experiments. In the experiment of Series 3 B, in which the intensity of the sounds of his footsteps was greatly reduced by stocking feet and a double thickness of carpet runner, he found himself, as he reported, "listening for the obstacle." He further stated that the pressure sensations "do not feel anywhere nearly as strong as before," and "I am not sure that I felt the screen at the greater distances" (that is, the 'first perceptions'). He was still certain, however, about the "pressures" in the 'final ap-

praisals.' A differentiation between the processes involved in the 'first perceptions' and the 'final appraisals' is suggested.

MS, who came to the study with the firm conviction that audition was the basis of the blind's perception of obstacles (or of his at least), completed the preliminary experiments with that bias undisturbed. In the B-series of every experiment, in which the intensity of his footsteps was greatly reduced, he walked toward the obstacle with his head turned to one side. This might have been done to increase the intensity or the area of his facial sensations, but he was of the opinion, when informed of this behavior, that he did it to aid audition - that is, that he was turning his better ear toward the obstacle.

The sighted *S*s, who approached the problem naively and without prejudice or theoretical bias, offered little in way of explanation in their early experiments. "Facial pressures" were reported by both. They were later explicitly denied by *JD* who reported that "the facial pressures which I thought for a while I was getting are, as I am now convinced, matters of imagination." In Experiment 2, he attributed his perception to sound. "Unless I shuffle my feet and make some noise," he reported, "I cannot perceive the obstacle." His dependence on sound was confirmed by his behavior; he shuffled his feet continuously as he advanced toward the obstacle. *PC* behaved similarly and probably for like reasons. In Series 3 B, in which conditions were optimally favorable, both of the *S*s independently ascribed their near approaches to the obstacle (that is, their 'final appraisals') to the effects of breathing. For example, *PC* reported, "I can feel my breath which comes back in my face when I get close to the screen"; and *JD*, "When I come close to the screen my breath seems to be reflected back into my face and I hear as well as feel it."

Besides furnishing norms with which later performances could be compared, the results of the preliminary experiments set the problems of the main experiments and shaped the procedures by means of which those problems were attacked.

MAIN EXPERIMENTS

The performances of our *S*s in the preliminary experiments may be explained by any one of a number of theories. For example, according to the classical "pressure theory," which one of our blind *S*s (*ES*) held and to which both of our sighted *S*s first subscribed and later denied, the perceptions of the obstacle by our *S*s were due to cutaneous pressure sensations localized chiefly in the face ("facial pressures"). These pressures are aroused, according to one variant of this theory, by reflected air currents or 'air waves' which are set up by the *S*s as they walk forward; or, according to another variant, they are aroused by the reflected sound waves originating chiefly in their footsteps. (We shall throughout this paper use the term 'air waves'

in a restricted sense to mean movements or currents in the air that are outside the audible range.) The classical "auditory theory," to which our other blind *S* (*MS*) adhered and our sighted *S*s at the end of the preliminary study were disposed, holds, on the other hand, that the perceptions of our *S*s were due to audition. The soundwaves from their footsteps were heard as they were reflected back from the obstacle.

Our principal task in the main experiments was to set conditions that would adequately test the rival theories and also enable us to determine what factors were *necessary* and *sufficient* for the perception.

Experiment 4

In the first of the main experiments, we sought to test the variant of the "pressure theory" that the basis of the "obstacle sense" is the pressure sensations aroused by reflected air currents or 'air waves.' If those sensations are the basis of the perception, the *S* should collide with the obstacle when conditions were so set that 'air waves' could not stimulate his skin. What does *S* do under such conditions? To answer that question we covered all of the exposed areas of his skin - his face, head, arms, and hands - and repeated the procedure of Experiment 3 which was adopted as standard for the main experiments.

Apparatus and Procedure

S's head was covered with a felt veil and hat and his arms and hands by rolled-down shirt sleeves inserted in the cuffs of wool-lined leather gauntlets (see Figures 6 and 7). The veil surrounding his head was supported by an insulite board into which a hole, the shape of his head, had been cut so as to fit him much as a hat. This board was 1/2 in. thick, 12 in. wide, and 16 in. in the greatest front-back demension, rounding to 14 in. at each side. A veil, 20 in. wide and composed of the heaviest felt obtainable, was glued and tacked to the edge of the board. It extended around the board and was overlapped across the back edge.[8] When this apparatus was placed on *S*'s head, the veil hung loosely down over his chest, shoulders, and back. At no place did it come into contact with his skin. It hung about 3 in. before his face - the approximate distance of his better 'final appraisals' in Experiment 3.

Figure 6 shows *E* placing the veil over *S*'s head while the latter is drawing on the gauntlets. The hat worn by *E* in this illustration was later, after the veil had been properly adjusted, transferred to the top of the insulite board as a cover to *S*'s head. (See Figure 7, which also shows *S*'s sleeves rolled down and inserted in the gauntlets.)

The veil eliminated air currents and 'air waves' but not

Figure 6. Felt Veil Being Placed Over S's Head.

Figure 7. S *Approaching the Movable Masonite Screen. He walked toward it with confidence and perceived it in every trial.*

soundwaves. The latter penetrated the veil; though intensity was slightly reduced, *S* was able to hear through it. That the former, on the other hand, were eliminated was amply demonstrated by the fact that *S* could not detect the 'air waves' of an electric fan blowing toward him from a distance of 10 ft, nor fanning movements of *E*'s hand made immediately in front of the veil. Conditions were, therefore, adequate in this exper-

iment to test the hypothesis that the "obstacle sense" was due to facial sensations aroused by the reflection of 'air waves.'

Incidentally, conditions were also adequate to test the explanation of the 'final appraisals' given by the sighted *S*s in Experiment 3 - namely, reflected breath which was either felt or heard or both.

Except for protecting the skin from the action of 'air waves,' the procedure in Experiment 4 was exactly the same as in Experiment 3 and, except for the omission of the paragraph regarding 'guidance,' the instructions were the same as in Experiment 1. After *S* was instructed, blindfolded,[9] and conducted to the anteroom, *E* placed the masonite screen in the position selected by planned haphazard choice, and led *S* to the starting position which had also been selected by planned haphazard choice. At a touch signal - no words again were spoken during the experiment - *S* walked toward the screen, designating his 'first perception' and 'final appraisal' as before.

A- and B-series were conducted as in Experiment 3, with the exception that the B-series came first in accordance with the counterbalanced order decided upon at the beginning of the study.

Results

Objective

All the *S*s, contrary to the doctrine of the pressure theory under consideration, perceived the screen and were able, as in the previous experiments, to report their 'first perceptions' and 'final appraisals.' Their performances - as measured by the average distances of their 'first perceptions' and 'final appraisals,' the ratios of those averages, and the number of times they collided with the screen (see Table IV) - did not equal those in Experiment 3 (see Table III), but the differences are of minor signifiance in comparison to the fact that the *S*s were able to perceive the screen without being stimulated by 'air waves.' Our results indicate, therefore, that the 'air wave' variant of the pressure theory is inadequate. Stimulation of the skin by 'air waves' is not a *necessary* condition for the perception.

This experiment, as indicated previously, also tested the statements of our sighted *S*s in Series 3 B that their reflected breath, heard or felt, was responsible for their 'final appraisals.' Had reflected breath been the basis of their judgments, no 'final appraisals' would have been made by them in this experiment because their breath could not escape the confinement of the veil and hence could not strike and be reflected back from the masonite screen. That 'final appraisals' were made by them, and at distances differing on the whole but slightly from those made in Experiment 3, indicates that some factor other than

TABLE IV

RESULTS OF EXPERIMENT 4

In Which all the Exposed Surfaces of *S*'s Skin Were Covered.

Series	Report	*ES*	*MS*	*PC*	*JD*
A	first perception (p) final appraisal (a) ratio (p/a) *S* ran into screen	8.56±1.94 .62± .18 13.8:1 0 times	7.44±2.01 .56± .11 13.3:1 1 time	1.44± .81 .70± .30 2.1:1 5 times	3.64±1.67 1.06± .85 3.4:1 2 times
B	first perception (p) final appraisal (a) ratio (p/a) *S* ran into screen	4.88±2.37 .62± .22 7.9:1 3 times	3.50±1.08 .64± .20 5.5:1 7 times	1.64±1.21 .66± .22 2.5:1 2 times	2.06± .54 .78± .29 2.6:1 2 times

breathing is responsible for those judgments. Reflected breath is not, therefore, *a necessary* condition for the 'final appraisals.'

A comparison of Tables III and IV shows:

1. that the ratios of performance are poorer in this experiment (Experiment 4) than in the control experiment (Experiment 3) for 3 *S*s (*ES*, *PC*, and *JD*) in the A-series and for 2 *S*s (*ES* and *JD*) in the B-series;

2. that the 'first perceptions' average less for 2 *S*s (*ES* and *PC*) in the A-series and for 1 *S* (ES) in the B-series;

3. that the 'final appraisals' average larger (that is, were poorer) for 2 *S*s (*ES* and *JD*) in the A-series and for all the *S*s in the B-series;

4. that the number of collisions are more frequent (that is, performance is poorer) for 2 *S*s (*PC* and *JD*) in the A-series and for all the *S*s in the B-series.

In general, however, the results of this experiment corrobrate those previously obtained: (a) the performances of the blind *S*s are superior to those of the sighted *S*s, and (b) the performances of all the *S*s are on the whole superior in

the A-series. Elimination of shoes on the hardwood floor (B-series) affects performance adversely.

PC's results are, however, an exception to the latter generalization. All the measures of performance are superior for her in the B-series. In comparison with the results of Experiment 3, her performances are markedly inferior in the A-series and slightly superior in the B-series.

Although again superior to all the other *S*s, *ES*'s performances in both series are poorer than in any of the previous experiments. In comparison with his results in Experiment 3, the distances of his 'first perceptions' average about 50 percent less, of his 'final appraisals' about 25 percent more, the size of his ratios were over 50 percent less, and the number of his collisions were increased from 1 to 3.

MS's performances, on the other hand, were better in every respect but one, that is, number of collisions. He ran into the screen once in Series 4 A and 7 times in Series 4 B in comparison to 3 and 3 times respectively in the A- and B-series of Experiment 3. The increase in Series 4 B, which it will be recalled was conducted first, was due in part to the veil-holder which projected about 3 in. beyond the tip of his nose. By the time *MS* came to Series 4 A, he had learned that he should not attempt to get too close to the screen.

Although *JD*'s ratios of performance were smaller in this experiment than in Experiment 3, the average distance of his 'first perceptions' were greater. He steadily improved throughout all the experiments in his ability to perceive the wall. The smaller ratios obtained here are due entirely to the increase in the average distances of his 'final appraisals.' The veil interfered with *JD* and the extent of the interference is indicated by the 50 to 60 percent increase in the distance of his near judgments.

S's Comments

The blind *S*s in this experiment gave the more significant reports. *ES* finally admitted his dependency on sound. He said during the experiments of Series 4 B, "I do not get an impression of the screen until I hear some little sound. I find myself scraping my stockings on the carpet in an endeavor to make a little noise." Again, "Creaks in the floor immediately give away the position of the screen." It was about the lack of sound that he complained, not about the lack of 'air waves,' and his behavior bore out his reports. He scraped his feet more and more as the series progressed, and when a creak from the floor occurred during an experiment his performance was greatly bettered.

MS reiterated his dependency on sound. "If there is complete silence," he reported, "I run into the screen." He too scraped his feet and made as much noise as possible within the limits al-

lowed him. Noises made normally in connection with walking were permitted *S*, but 'artificial' noises, such as jingling coins or keys in his pockets, snapping his fingers, slapping his thighs, whispering, hissing, whistling, and the like, were denied him.

PC merely reported that she could not "hear well," that her judgments were "difficult," and that she was "very uncertain about them." In Series 4 A, the second in Experiment 4, she stated, "I still do not know what the basis of my judgment is." *JD* hazarded no comment during this experiment beyond reporting that the veil "reduced hearing." The behavior of both the sighted *S*s indicated, however, their dependency upon sound. They scraped their feet continuously, more than in any of the previous experiments, and advanced toward the screen in a hesitant, shuffling walk.

Discussion and Conclusions

1. The result of principal interest in this experiment is the finding that stimulation of the skin by reflected 'air waves' ("facial pressure") is not a *necessary* condition for the perception of obstacles. Whether it is a *sufficient* or even a *contributing* condition cannot be answered definitely from the results at hand. To determine *sufficiency*, experimental conditions must be so cut as to eliminate all other factors. Since those conditions are approximated in Experiment 5, discussion of the question of sufficiency will be left until the results of that experiment are reported.

Certain results - for example, the decrement of *ES*'s performance in both the A- and B-series - seem to indicate, however, that 'air wave' stimulation was a contributing condition. *ES* believed, it will be recalled, that his judgments were based on "facial pressures." In confirmation we find that his performance declined when 'air wave' stimulation was eliminated. May the decrement be explained by the loss of that stimulation, and may the amount of the decrement be regarded as the amount of the contribution? That is a possibility, but if that be accepted as the explanation of the decrement in *ES*'s performances, what is the explanation of *MS*'s improvement? It was as marked in this experiment as *ES*'s decline. Can the same condition be used to explain a decrement in one case and an increment in another? It can be tried! *MS*, it will be recalled, believed that his judgments were based on hearing. It may be, therefore, that 'air wave' stimulation, which was operative in the control experiment, was a distraction for him. When this distraction was removed, as in this experiment, his performance improved. An appeal to individual differences in the effect of 'air waves' may thus account for *ES*'s and *MS*'s discrepant results. Can the explanation be extended to the results of the sighted *S*s? *PC*'s performances showed a marked decrement in the A-series and a slight improvement in the B-series. In the experiments of Series 3 A, in which she walked on the hard-

wood floor, the stimulation by 'air waves' may have been intense enough to have contributed to her perceptions. Their loss in Series 4 A may, as in *ES*'s case, explain the decrement in her performances in that series. In the B-series, in which she walked in stocking feet on carpet runners, the stimulation may not have been sufficiently intense to have been of any help to her. Their loss in that case would have no effect and she would do as well as when they were present. She did better; but the improvement may be a matter of practice and in no way connected with the presence or absence of 'air waves.' *JD*'s results cannot be explained on the basis of the present discussion.

Not only does 'air wave' stimulation fail to explain *JD*'s results, but the explanation of the results of the other *S*s is labored. It does not rest upon facts of observation because none of the *S*s, not even *ES*, reported the lack, loss, or want of 'air wave' stimulation. All of them did, however, report the decrement in hearing caused by the blanketing effect of the veil, and all tried to make up for that loss by increasing the intensity of the noise they made in walking toward the obstacle. A simpler explanation of the decline in *ES*'s performance than the one given above is the decrement in his hearing. His performances were poorer in Experiment 4 because the veil reduced the intensity of the soundwaves.

The 'soundwave' theory explains *ES*'s results, but it leaves unexplained *MS*'s improvement and *PC*'s ambiguous results. The 'air wave' theory does better, but it rests upon assumptions that are entirely hypothetical.

2. The findings concerning stimulation by reflected breath are similar to those regarding stimulation by 'air waves': reflected breath is not a *necessary* condition of the 'final appraisals,' and the limitations of this experiment do not permit us to determine whether it is a *sufficient* or even a contributing condition. The decrement in the *S*s' performance in their 'final appraisals' might be taken to indicate that 'reflected breath' contributed to those judgments, but it might equally well be explained by the lack of 'air wave' stimulation or by the loss in hearing that the wearing of the veil also entailed. Indeed, it might better be explained by the latter because all of the *S*s reported hearing losses and tried to compensate for them by walking noisily. None of the *S*s, however, mentioned the loss or lack of reflected breath.

3. That the *S*s were able, under the special conditions of this experiment, to perceive the obstacle and to approach closely to it, indicates that echoes of the soundwaves, either felt or heard (and this experiment does not permit decision on that point) are *sufficient* conditions for their judgments. Whether they are *necessary* conditions is a question that will specifically be considered in the experiments which follow.

4. The quality of the *S*s' performances in their 'first perceptions' (as measured directly by distance) was no guarantee of the quality of their performances in their 'final appraisals' (as measured inversely by distance). In comparison with the results of the control experiment (Experiment 3), the quality of *ES*'s paired judgments in both the A- and B-series and of *MS*'s in the A-series varied concomitantly - *ES*'s performances decreased, *MS*'s increased. On the other hand, the quality of *MS*'s paired judgments in the B-series and of *PC*'s and *JD*'s in both series varied inversely. Except for *PC* in the A-series, an increase in the quality of their 'first perceptions' was followed by a decrease in their 'final appraisals.' For *PC* in the A-series, a decrease in the quality of her 'first perceptions' was followed by an increase in that of her 'final appraisals.'

The lack of consistency among the results of the *S*s corroborates the conclusion tentatively drawn in the preliminary experiments that the 'first perceptions' and 'final appraisals' rest upon different sensory bases.

Experiment 5

In Experiment 5, we sought to answer three questions that derive from Experiment 4.

1. Are reflected soundwaves (felt or heard) *necessary* conditions for the perception of obstacles?

2. Are 'air-' or soundwaves reflected to the exposed areas of the skin (felt) *sufficient* conditions for the perception of obstacles?

3. Are reflected currents of breath (felt or heard) *sufficient* conditions for the close approach ('final appraisal') of the obstacle?

The first question is of primary concern because experimental conditions which bring the answer to it are also adequate for answering the second and third questions.

Setting conditions to answer the first question is not, however, a simple matter because reflected soundwaves may be felt or heard. Because it would be extremely difficult, if not impossible, to construct a shield that would keep soundwaves from penetrating it and reaching the skin, we decided to attack first the question of hearing. We did this, not only because hearing could be eliminated much more easily than 'feeling,' but also because of the possibility, indicated by the results in the B-series of the preceding experiments, that 'feeling' should not have to be considered when the answer regarding 'hearing' was obtained.

Stopping *S*'s ears is relatively a simple matter, but the problem of separating hearing from 'feeling' is far more complex. We do more than block hearing when we stop *S*'s ears. We also shield the external auditory meatus and the tympanic membrane from stimulation - areas which, as James suggested in 1890, might be the source of the pressure sensations that serve as the basis of the "obstacle sense" (18, pp. 204 ff).

Be that as it may; if we cannot separately investigate the function of the two modalities in the "obstacle sense," we can at least define and state our problem clearly. Rephrased, the first question is as follows: "Is aural stimulation (felt or heard) by reflected soundwaves (echoes) a necessary condition for the perception of obstacles?" That question is specific and capable of investigation. To answer it we stopped *S*'s ears, leaving the normally exposed areas of the skin open and free for stimulation by 'air waves,' air currents, soundwaves, and reflected breath. If, under those conditions, *S* failed to perceive the obstacle, ear stimulation would be shown to be a *necessary* condition and we should also have evidence to answer the second and third questions posed by Experiment 4. Such results would not, however, confirm the "auditory theory" that the "obstacle sense" was due to hearing but they would disprove both variants of the "pressure theory" that the basis of the "sense" was *facial* pressures aroused by 'air-' or soundwaves.

Apparatus and Procedure

S's ears were stopped as follows. Into the external auditory meatus of each ear an MSA Ear-Defender was inserted.[10] Over the defender and fitting snugly into the concha, a plug composed of a mixture of beeswax and cotton wool was placed. Over this plug and conforming to the convolutions of the pinna was a beeswax-cotton shield. Over this shield were two layers of cotton batting. These layers were held in place by a pair of ear muffs which were themselves lined with cotton wool. All of these layers were held tightly to *S*'s ears by the elastic bands of the blindfold that was placed on *S* as in the other experiments. Under these conditions (see Figure 8) all the *S*s were deaf to ordinary sounds. Though they still were able to hear loud shouts and noises, they could not hear the sounds of their footsteps nor normal conversation. The hearing loss, for the only *S* (*JD*) for whom it was measured, was 65 dB.

Except for the blindfold, which was used for the blind and sighted *S*s alike, *S*'s face was uncovered and open to cutaneous stimulation by 'air waves,' air currents, soundwaves, and reflected breath.

The procedure and instructions were the same as in the control experiment, Experiment 3. In accordance with the counter-balanced order of conducting the A- and B-series, we began this experiment

with the A-series.

Figure 8 shows one of the *S*s (*JD*) with ears stopped walking on the floor between the carpet runners toward the masonite screen.

Results

Objective

None of the *S*s in either series was able to detect the obstacle under the conditions of this experiment. They collided with the screen in 50 consecutive trials in each series - that is, 100 trials for every *S*. Except for the directional orientation given them by the carpet runners, they were completely 'lost' - and as completely lost in the A- as in the B-series, and in the last of the 100 trials as in the first. There was no indication of learning whatsoever.

The posture of the *S*s during the approach was very different from that in any of the preceding experiments. They walked with head thrust forward as if they were straining to hear, which they were, as their reports showed.

S'*s Comments*

All the *S*s reported that they were "unable to hear." *ES*, who, it will be recalled, was certain at the outset of the study that his judgments were based upon "facial pressures" and that sound played no role in them, reported, "I am not getting any sensations at all." For the first time in this study he walked forward with his hands held up apprehensively in front of him. *MS* reported, "I cannot get any cues at all." "The curtain of facial pressures that I once reported were pure fancy" (see Figure 9). *PC*, who perceived the obstacle 7 times in trials 5 through 19 in the A-series from distances of 2 to 4 in. (comparable to the distances of her 'final appraisals'), reported after trial 19 that she blew her breath forcibly through her lips as she walked forward and that she perceived the obstacle when she got close to it "by puffs of air reflected" to her face. When these 'successful' trials were repeated and the series continued with the added instruction to keep her lips closed and to breath normally through her nose she collided with the screen at every trial because she had, as she reported, "no cues whatsoever; don't get a thing."

Discussion and Conclusions

The results of this experiment lead to the following conclusions.

1. Aural stimulation, felt or heard, is a *necessary* condition for the perception of obstacles by our *S*s. Under the conditions of this experiment we cannot determine whether pressure

Figure 8. S *Approaching the Movable Masonite Screen with Ears Covered. Audition was Reduced by 65 dB.*

Figure 9. S *Walked Toward the Screen Hesitatingly and Ran Into It in Every One of 50 Trials, As Did All the* Ss.

stimulation from the external ear (meatus and tympanum) or audition is the necessary condition. Although willing to hazard the opinion that our *S*s' failure to perceive the obstacle was due to the loss of audition - all the *S*s reported that loss and none the loss of cutaneous pressure, aural or facial - we have neither the right nor the desire to be dogmatic nor do we wish to transcend our results. A decision concerning this point can be reached only through further experimentation. Experiments with deaf *S*s having inner-ear defects, who could serve without stopping their ears - thus leaving the meatuses and tympanums open to pressure stimulation - would be crucial. They are anticipated.

2. The faces, arms, and hands of our *S*s were open to stimulation by 'air-' and soundwaves. If those stimuli were sufficient for the perception of obstacles, our *S*s would not have failed to have detected the masonite screen. That they did fail warrants the conclusion that 'air-' and soundwaves reflected to the skin are not *sufficient* conditions for the perception of obstacles by our *S*s. Both variants of the "pressure theory," insofar as the theory rests on "facial pressures," are therefore untenable.

3. Forcible breathing - that is, blowing puffs of air forward through the lips - was discovered in the case of one *S* (*PC*) who expelled her breath in that fashion during her progress to the screen to be a *sufficient* condition for the close approach ('final appraisal'). Had the other *S*s employed her method, they too must have had similar successes, but the fact that neither she nor they perceived the screen when they breathed normally through the nose justifies the conclusion that reflected currents of air normally aroused in breathing are not, insofar as 'feeling' is concerned, *sufficient* conditions for the perception of obstacles by our *S*s. The ears

were eliminated, hence no statement concerning the aural effects of reflected breath is justified. This experiment was not adequate to test that point.

4. The conclusion tentatively drawn in the preliminary experiments and confirmed in Experiment 4 that the *S*s' paired judgments ('first perceptions' and 'final appraisals') rest on different sensory bases seems at first consideration to be negated by the results of this experiment. Such, however, is not the case. That the *S*s collided with the obstacle and were unable to make those reports does not mean that their 'first perceptions' and 'final appraisals' have the same sensory basis, but indicates only that ear stimulation is a *necessary* condition for both of those judgments. It may well be that the paired judgments have different sensory bases: one of the pair may rest on hearing and the other on pressures from the cutaneous membranes of the meatuses and from the tympanums, but upon that point this experiment casts no light. Beyond restricting the paired judgments to the ears, the results reported here have no bearing upon that conclusion.

5. Although the conclusion drawn in 2. that reflected 'air-' and soundwaves are not *sufficient* conditions for the perception of obstacles by our *S*s, seems to be justified by the facts at hand, it may be questioned on the grounds that the results are artifacts of the method - that the failures of our *S*s to detect the masonite screen in this experiment were due, not to the lack of ear stimulation, but to the deleterious effect of the loss of hearing on cutaneous perception. This is a possibility and, remote though we believe it to be, it is one that should be investigated before further experiments on the main problem are undertaken. We turned aside at this point, therefore, from the central theme of our study and sought in the following experiment to obtain evidence that would confirm or deny our original conclusion.

Experiment 6

Our problem in Experiment 6, a digression in our main study, is definite and specific. Is pressure stimulation of the exposed areas of the skin by reflected 'air-' or soundwaves a *sufficient* condition for the perception of obstacles when hearing is left functionally intact? Was the loss of hearing, in other words, responsible for our *S*'s failure in the preceding experiment to perceive the obstacle by means of cutaneous pressure?

To answer those questions we had to set conditions that would meet three requirements:

1. *S*'s ears must be shielded from 'air-' and soundwaves reflected by the obstacle so the obstacle would not be perceived by means of the aural mechanisms;

2. his face and other exposed cutaneous areas must be free and open for stimulation by those waves;

3. his hearing must not be eliminated nor in any way adversely affected.

We met those specifications by means of a sound screen, which shielded *S*'s ears by drowning out the reflected waves, left his face and other cutaneous areas free and open for stimulation, and neither eliminated nor affected his hearing adversely.

Apparatus and Procedure

The sound screen, a constant, continuously sounding tone of moderate intensity, was produced by means of an electrically driven tuning fork of 1000 cycles. The stimulus source was shielded and the tone was conducted by long, pliant wires to a set of headphones worn by *S* over his ears. There was, consequently, no sound in the experimental room other than that made by *S* in approaching the obstacle. The phones, which were cushioned by sponge-rubber pads, were held firmly in position against *S*'s head by means of the elastic bands of the blindfold. Figure 10 shows the headphones and blindfold being put in place. Care was taken in placing the headphones to see that the diaphragms of the phones and the openings in the pads were opposite the meatuses of *S*'s ears.

Except for the substitution of the soundscreen for the Ear-Defenders, plugs, and cotton pads, the procedure and instructions were the same as in Experiment 5. We began with the A-series of experiments because conditions in these were more favorable for the perception of obstacles than in the B-series. If the *S*s succeeded under the more favorable conditions, then we could turn to the less favorable; but if they failed under them, then there would be no need to turn to the less favorable.

Results

Objective

Again, as in Experiment 5, all of the *S*s ran into the masonite screen in every trial - that is, 50 for every *S* (see Figure 11). The B-series was consequently omitted.

The behavior of the *S*s was similar to that in Experiment 5. All walked slowly and more noisily than in any of the preceding experiments. *ES* and *PC* approached the obstacle with hands held apprehensively before them; and *MS* and *JD* with the bodily posture of a listener.

Figure 10. Sound Screen Being Placed Over S'*s Ears.*

Figure 11. S *Colliding with the Movable Masonite Screen. He, as did all the* Ss*, ran into the screen in every one of 50 consecutive trials.*

S'*s Comments*

All the *S*s reported that their "ears were full of tone" and that they heard no sounds, despite the increased noise made in walking, other than the tone of the sound screen.

Discussion and Conclusions

The results of this experiment indicate, as we believe, that the *S*s' failure or inability to perceive the obstacle in Experiment 5 was due, not to a hypothetical, deleterious effect of the loss of hearing upon cutaneous perception but to the absence of aural cues which were eliminated by the earplugs and pads in that experiment and were submerged by the sound screen in this one. Because the findings in Experiment 5 are corroborated by those in this experiment, we feel justified in reaffirming the conclusions drawn there:

1. that aural stimulation, felt or heard, is a *necessary* condition for the perception of obstacles by our *S*s;

2. that 'air-' and soundwaves reflected to the skin are not *sufficient* conditions for the perception;

3. that reflected breath in normal breathing is not, insofar as "facial pressure" is concerned, a *sufficient* condition for the perception.

The results of this experiment also indicate, in confirmation of the results of Experiment 5, that ear stimulation is a *necessary* condition for both of the paired judgments ('first

perceptions' and 'final appraisals'). The results cast no light, however, on the question regarding the sensory basis of those judgments, because ear stimulation yields pressure as well as auditory sensation.

Experiment 7

In Experiment 4, we tested one variant of the pressure theory of the "obstacle sense" by eliminating the 'air waves' that might have stimulated the exposed areas of the skin. The ears and the skin were left open to stimulation by soundwaves. If obstacles were detected by means of pressure sensations aroused by 'air waves,' our *S*s should have failed in that experiment. That they did not fail led us to conclude that stimulation of the skin by 'air waves' is not a necessary condition for the perception of obstacles by our *S*s.

In the present experiment, Experiment 7, we wished to carry the study one step further and test the second variant of the pressure theory by eliminating the soundwaves that might stimulate the exposed areas of the skin. This would have to be accomplished without excluding the soundwaves from the ears, otherwise we should not know whether the results obtained were due to the elimination of the ears or of the skin.

The required specifications were clear and straightforward enough, but meeting them was quite another matter. After many unsuccessful attempts, we finally obtained the desired experimental conditions by placing *S* in a soundproof room - thus removing his exposed cutaneous areas from the effects of standing 'air-' and soundwaves - and having him judge *E*'s approach to an obstacle by means of the sounds transmitted electrically to headphones on his ears. Stimulation was thus localized in *S*'s ears. If under those conditions *S* was able to perceive the obstacle, the conclusions drawn in the preceding experiments would be corroborated: namely, that ear stimulation was a *sufficient* condition for the perception of obstacles by our *S*s, and that stimulation of the exposed areas of the skin was not a *necessary* condition.

Apparatus and Procedure

As Figure 13 shows, *S* sat in a comfortable chair in a soundproof room with high fidelity headphones over his ears and a telephone transmitter in his hands. (For a description of the soundproof room see reference 2, p. 297 ff.) The headphones were connected through a power amplifier to a directional microphone.[11] The microphone was carried at shoulder height by *E* (see Figure 12) as he walked from varying starting points in the hall to the end wall - the same obstacle used in Experiment 1 and used again for similar reasons; namely, because it was large and highly reflecting, hence maximally favorable for the present problem.

Figure 12. E *with Earphones on His Head Approaching the Wall with the microphone in His Right Hand Held Shoulder High.* S *is in a soundproof room with high-fidelity earphones which are connected through a power amplifier with the microphone held by* E. *He listens to the sounds of* E*'s footsteps and judges* E*'s approach to the wall.*

Figure 13. S *in the Soundproof Room with Earphones and Transmitter. He judges* E*'s approach to the wall and tells* E *when to proceed and when to stop. He judged without difficulty* E*'s approach to the wall.*

The transmitter held by *S* was connected to headphones worn by *E* (Figure 12) so that *E* and *S* were able to communicate with one another as occasion demanded - *E* speaking into the microphone and *S* into the transmitter. *E* could, by means of a switch in the handle of the microphone, break the circuit and cut *S* off from the sounds of the experimental room.

E, wearing leather soled and heeled shoes, walked on the hardwood floor from various starting points to the wall. The starting points, selected in planned haphazard order, were 6, 12, 18, 24, and 30 ft from the wall - the distances used in Experiment 3. The microphone circuit was broken after every trial. During the intervening intervals *E* recorded the results of the trial just made and then went to the starting point of the next following trial. When *E* was at that point he again closed the microphone circuit, informed *S* by a "ready, now" signal that he was starting toward the obstacle, and then in slow, even steps walked forward to the wall.

S was instructed to listen to the sounds of *E*'s footsteps during the approach and to report over the transmitter when the wall was first perceived and when the microphone was just about to touch it - the 'first perceptions' and the 'final appraisals' of the preceding experiments.

E walked to the wall at two rates: moderately slow and slow. He started 'moderately slow' and continued uniformly at that rate until requested by *S* to walk more slowly; a request frequently though not always made when *E* had reached the point critical to *S*'s first perception of the wall. *E* immediately complied with the request, but, whatever the rate used, it was as uniform within those ranges as *E* could make it.[12]

E went forward until he had bumped the microphone against the wall or until *S* said "there" as a signal of his 'first perception' of the wall. At that signal, *E* stopped and noted from a tape measure on the floor his distance from the wall to the nearest 6 in. Then, without a signal (a spoken word would have supplied unwanted cues), he stepped forward and continued at a uniform rate until he had bumped the microphone against the wall or until *S* gave a signal of his 'final appraisal' of the wall by saying "stop," at which point the distance from the wall was again noted to the nearest 6 in.

Amplification of the sounds from the experimental room was set at a stage to suit the individual *S*s. Except for the changes here reported, the procedure in this experiment was the same as in Experiment 3.

Results

Objective

One series of 25 successful trials was completed by every *S*. All

the *S*s were able, even under the unusual conditions of this experiment, to perceive the 'far' and 'near' approaches and they collided with the wall - that is, permitted *E* to strike it with the microphone, not much more frequently than they did in the control experiment, Experiment 3. As Table V shows, *E* ran into the wall 1 time for *ES*, 2 times for *MS*, 3 times for *PC*, and 4 times for *JD* as against 0, 3, 1, and 1 times respectively for the *S*s in Series 3 A, and 1, 3, 1, and 1 times in Series 3 B. All of the 'collisions' in this experiment occurred on the 'near' approach, after the *S*s had signaled their 'first perceptions' and were trying to better their performances in their 'final appraisals.' Had the *S*s been able to control the rate of *E*'s advance, as they controlled their own rate in Experiment 3, the number of collisions would, as we believe, have been fewer.

TABLE V

RESULTS OF EXPERIMENT 7

In Which *E* Carried a Microphone from Varying Starting Points Toward Wall and *S* Sat in a Soundproof Room Listening to Sounds of *E*'s Footsteps and Giving Judgments of *E*'s Approach to the Wall.

Report	*ES*	*MS*	*PC*	*JD*
first perception (p)	10.20±1.12	6.04±1.80	6.60±2.77	2.92±1.09
final appraisal (a)	2.74± .34	.94± .46	1.60± .24	.82± .35
ratio (p/a)	3.7:1	6.4:1	4.1:1	3.6:1
E ran into wall	1 time	2 times	3 times	4 times

In comparison with the results of Experiment 3 (see Table III), performance in this experiment was much poorer for *ES* but only slightly if any poorer for the other *S*s. *ES*'s ratio of performance was 3.7 as against 34.2 in Series 3 A and 16.3 in Series 3 B. The greatest decrement in his performance was in his 'final appraisals': 2.74 ± .34 ft as against 0.50 ± .00 ft in both Series 3 A and 3 B. Indeed, his 'first perceptions' (10.20 ± 1.12 ft), although poorer than those in Series 3 A (17.08 ± 6.96 ft), were better than those in Series 3 B (8.16 ± 5.58 ft). The mv of his 'first perceptions' were, however, much smaller (10.9 percent) than in Series 3 A and 3 B (40.7 percent and 68.3 percent respectively). The relative sizes of the mv suggests that the cues that served as the basis of his 'first perceptions' were more constant, though

weaker, in this experiment than in Experiment 3.

Performance of the other *S*s differed but slightly from that in Series 3 A but was superior to that in Series 3 B. For all of the *S*s, however, the 'final appraisals' were, as in *ES*'s case, poorer than in either Series 3 A or 3 B. Despite the decrement in their 'final appraisals,' *MS* and *PC* improved their 'first perceptions' so greatly that the ratios of their performances are of the same order as those in Series 3 A and superior to those in Series 3 B.

S's Comments

All of the *S*s reported that they were able to judge *E*'s approach toward the wall by means of the transmitted sounds - and their performances bore them out. They all stated, furthermore, that the sounds of *E*'s footsteps were different from those heard when they themselves were doing the walking. *ES* reported that the sounds "were less real, like those through a telephone"; *MS*, "not as clear, duller and of a different quality"; *PC*, "less bright"; and *JD* that "the higher partials seem to be lacking."

In answer to the question: "Upon what do you base your judgments?" - which was asked the *S*s during and after the trials - all reported that they based them upon changes in the sounds of *E*'s footsteps which occurred when he came near the wall. *ES* said, "I report as soon as I notice a change"; *MS*, "My reports are based on changes in the sounds"; *JC*, "sound changes, of pitch I think"; and *JD*, "upon change, a rise in pitch I believe." None of the *S*s were able, however, to differentiate between their judgments of the 'first perceptions' and the 'final appraisals.'

Discussion and Conclusions

Because the *S*s were able to perceive the wall when stimulation was limited to the action of soundwaves on their ears, we feel justified in reaffirming the following conclusions which have previously been drawn:

1. aural stimulation by soundwaves is a *sufficient* condition for the perception of obstacles by our *S*s;

2. stimulation of the face or other exposed areas of the skin by 'air-' or soundwaves is not a *necessary* condition for the perception;

3. both variants of the pressure theory, insofar as they apply to the exposed areas of the skin, are untenable;

4. reflected currents of air, originating from breath-

ing, are not *necessary* conditions for our *S*s' 'final appraisal' of the obstacle.

The results of this experiment confirm, furthermore, the conclusion of Experiment 5 that the paired judgments ('first perceptions' and 'final appraisals') depend upon aural stimulation. They gave us no decisive information, however, regarding the conclusion tentatively drawn in the preliminary experiments, and reaffirmed in Experiment 4, that those judgments rest upon different sensory bases. Aural stimulation is not limited in its effects to audition. Pressure may also be aroused; and if it is, it could serve as the basis of one of the paired judgments and audition the other. The results of this experiment do not, therefore, invalidate this tentative conclusion any more than did the results of Experiment 5 and 6. Besides restricting the judgments to sensory cues derived from the ears, the results of this experiment have no direct bearing upon the point at issue.

The reports of the *S*s indicate, however, that the principal basis of their judgments was audition. All reported changes in sound and two of them (*PC* and *JD*) specifically mentioned pitch, but none of them at any time mentioned pressure.

The lack of the higher sound frequencies - frequencies above 12,000 cycles (see footnote 11) were beyond the designated range of our apparatus - was noticed and reported by all the *S*s. Since the *S*s' performances were poorer in this experiment than in the control experiment, our inference is that the higher frequencies play an important role in the perception of obstacles.

SUPPLEMENTARY EXPERIMENTS

At the conclusion of Experiment 7 two supplementary experiments were conducted with *MS*. The first was with monaural hearing and the second with pseudophones.

Supplementary Experiment 1: Monaural

MS's right ear, his poorer one, was stopped as in Experiment 5 and one series of experiments was conducted according to the procedure used in Experiment 3. No other change, except the blocking of one ear, was made in the method.

Results

MS was able with one ear to perceive the obstacle (the mason-

ite screen). He failed in none of his 'first perceptions' and ran into the screen on his 'near' approach but once and then only because he was trying to improve his performance. The average distance of his 'first perceptions' and 'final appraisals,' and the ratios of those averages are given in Table VI. The 'final appraisals' do not average as near to the obstacle as in the control experiment (Experiment 3), but in every other respect his performance is better in this series (cf. Tables III and VI).

TABLE VI

RESULTS OF THE SUPPLEMENTARY EXPERIMENTS WITH *MS*

Report	Monaural	Pseudophones
first perception (p)	11.76±3.55	6.44±1.84
final appraisal (a)	.62± .18	.60± .16
ratio (p/a)	18.9:1	10.6:1
S ran into wall	1 time	3 times

We do not interpret those results to mean that monaural stimulation is superior to binaural for, despite the results, we do not think that it is. The improvement in this series is, as we believe, due to the effects of practice. *MS*, it will be recalled, was the experimental guinea pig in this study. Everything was tried on him before it was used with the other *S*s and he was given many more series in the various experiments than the other *S*s (for example, four series in Experiment 1, three in Experiment 4, five in Experiment 7) to enable us to judge whether the series length or number should be increased. Consequently, he was highly practiced in the perception of obstacles and thoroughly familiar with the experimental method. The superiority of his performance in this series over the control is not, therefore, surprising. Even under the severe handicap of the conditions of Experiment 7, his performance was approximately equal to that in the control experiment.

The point, however, is not of great significance. The important result of this experiment is that monaural stimulation is a *sufficient* condition for the perception of obstacles. The "obstacle sense" is not, like auditory localization, dependent upon binaural stimulation.

Supplementary Experiment 2: Pseudophones

In the second supplementary experiment, Young's pseudophones were placed on *MS*'s head and ears and the procedure of Experiment 1 was used (43, pp. 400 ff).

Results

Though greatly confused in his spatial relations, *MS* was again able to perceive the obstacle (the end wall of the hall). He achieved this, however, only by keeping the pseudophones parallel to the wall. When he turned his head slightly and brought the phone out of the parallel line his movements were bizarre. He zigzagged down the hall, going in directions opposite to those desired - backing up when he should have gone forward and veering to the right when he should have turned to the left.

In contradistinction to the results of Experiment 1, he was easily disoriented in this series. A few turns around the hall left him completely confused. He could not, moreover, walk from the starting point to the wall in a straight line. If, for example, he actually veered to the left (a deviation that he would normally have corrected very quickly by turning to the right), he perceived the deviation as at the right, and accordingly turned further to the left. This increased the perceived deviation to the right and he again turned further to the left, thus compounding his error. It was not until he learned to turn into his 'errors' instead of away from them that he was able to proceed down the hall without guidance, and even then his progress was a succession of short turns and readjustments.

Under the unusual conditions of this experiment, *MS* ran into the wall but three times, on all those occasions he had reported his 'first perception' of the screen and was attempting to make his 'final appraisals.' The averages of his 'first perceptions,' 'final appraisals,' and the ratio of those averages are given in Table VI.

These results are on the whole superior to those obtained in the control experiment (cf. Tables III and VI) - evidence, not that pseudophonic stimulation is superior to normal, but of the effect of practice. *MS* was blind from early childhood, and he was highly skilled in the perception of obstacles when he entered upon this study. The fact that he improved by practice is evidence that other blind people could do likewise.

The result of principal interest in this experiment is the bare fact stimulation of the ears, even though given through pseudophones is a *sufficient* condition for the perception of obstacles.

SUMMARY OF RESULTS AND CONCLUSIONS

In this study we dealt with two different sources of sensation: the exposed areas of the skin and the ears. With each of those sources of sensation two kinds of stimuli concerned us: air currents and 'air waves' which were outside the auditory range, hence they could arouse only cutaneous sensation if they aroused anything; and soundwaves which could be heard and which might also be capable of arousing cutaneous sensation in the ear and the exposed areas of the skin. It was upon those variables that we ran our experimental changes.

We eliminated the action of 'air waves' and air currents on the exposed areas of the skin but left the skin and the ears open to stimulation by soundwaves; we plugged the ears and shielded them from stimulation but left the exposed areas of the skin open to stimulation by 'air-' and soundwaves; we drowned by means of a sound screen all stimuli which might have reached the ears but again left the exposed areas of the skin open to stimulation by 'air-' and soundwaves; and lastly we reduced the stimuli to soundwaves and limited their action to the ears.

The results obtained from those experimental changes led us to the following conclusions.

1. Stimulation of the face and other exposed areas of the skin by 'air-' and soundwaves is neither a *necessary* nor a *sufficient* condition of the perception of obstacles by our *S*s.

2. Stimulation of the skin by reflected breath is neither a *necessary* condition nor, as far as 'facial pressure' is concerned, a *sufficient* condition for the 'final appraisals' by our *S*s.

3. The pressure theory of the "obstacle sense," insofar as it applies to the face and other exposed areas of the skin, is untenable.

4. Aural stimulation is both a *necessary* and a *sufficient* condition for the perception of obstacles by our *S*s.

The conclusion is corroborated by the results of two recent studies on bats by Griffin and Galambos (10, 11). In the first study, the authors discovered by means of deprivation procedures (for example, gagging the bat to prevent production of supersonic cries [30 to 70 kc], blindfolding, waxing the wings, plugging the ears) that the frequency of hitting obstacles increased above chance when the bat was deprived of sound cues either by gagging so it could not produce the cries or eliminating hearing so it could not hear the cries it made. They concluded from the results

of their study that "flying bats detect obstacles in their path by (1) emitting supersonic notes, (2) hearing those sound waves when reflected back to them by the obstacles, and (3) detecting the position of the obstacle by localizing the source of this reflecting sound" (10, p. 505).

In the second study, the authors identified more closely the pitch frequencies and the rate of emission of the bats' cries. They found that supersonic cries, unique to every bat, were emitted at the rate of about 30 per sec when the bat was flying through unobstructed space, that the rate increased to about 50 per sec when approaching an obstacle, and that it dropped to 30 again when the obstacle was passed. Because this drop never occurred when bats had been deafened and thus rendered unable to avoid obstacles, Griffin and Galambos conclude that "the supersonic cry plays an important role in normal obstacle-avoidance" (11, p. 490).

FOOTNOTES

1. Supa, who was blind and possessed the "sense of obstacles" in a high degree, was convinced that audition was the basis of the phenomenon. He snapped his fingers and clicked his heels on the floor as aids in the perception. Cotzin, who approached the problem for the first time when he came to this study, was unprejudiced. Dallenbach, as the results of an unpublished study performed on a blind student in 1914, was biased in favor of the "pressure" theories.

2. Boards of other composition were tried, but masonite proved the most satisfactory. Plywood boards, unfinished or finished with shellac, varnish, paint, or wax, could be detected very easily by the *S*s through odor.

3. We are indebted to Dr. E. H. Cowell of Ithaca, New York, for this examination and report and for his interest and cooperation throughout the course of the experiments.

4. After the first series, distances were measured in units of 6 in. Performance did not require more accurate measurement and the distances of *S* from the wall could not easily be measured more accurately by means of the tape measure laid on the floor.

5. Starting points at distances of 30 ft and greater should have been used alone for him, but points that suited him would not have suited the other *S*s. We wished to keep conditions uniform among the *S*s. Moreover, the hall in which the experiments were conducted was not, because of the stairway and well at one end, adapted for distances much greater than the

longest used. To have used only the longer distances with him would have set his results out of line with those of the other *S*s. Therefore, in order that we might compare directly the results of the different experiments we sought to keep all the conditions as constant as possible except those varied for a purpose. The decision to use the same starting points for *ES* as for the other *S*s was wise, as it later developed, because the distances used were adequate for him in the main experiments.

6. Had the *S*s been allowed to go beyond the end of the path, they would have become aware of the check experiments. We wished to keep them uninformed of the introduction of those experiments so their attitude would be unchanged. As far as we know, none of the *S*s suspected their introduction.

7. The rank order correlation between the paired judgments for *ES* is -0.14; for *MS*, -0.10; and for *JD*, -0.21 - values so small that chance is indicated. For *PC*, however, a correlation of -0.97 was obtained, a value much too high for chance.

8. The overlap at the back was necessary as otherwise, when placed on *S*'s head, a gapping hole was left in the veil at the nape of his neck through which 'air waves' might have had access to the cutaneous areas of his face. The overlap obviated that difficulty.

9. *S* was blindfolded even though the veil was lightproof in order to keep constant, in all of our experiments, the size of the facial area that was or might be subject to stimulation. Figure 6 shows *S* wearing the blindfold.

10. MSA Ear-Defenders, HA-15369, are obtainable in two sizes from the Mine Safety Appliances Co., Pittsburgh, Pennsylvania. The Ear-Defender is a tapered rubber tube containing an outer barrier of heavy metal and an inner barrier of soft rubber. There are thus two barriers or partitions separated by an air space through which the noise must penetrate before it can strike the ear drum.

11. The apparatus was loaned to us by WHCU, the Cornell University Ratio Station. Our thanks are due to Professor True McLean and Professor W. D. Moeder for advice and assistance in this phase of the study. The microphone was an RCA Pressure Microphone, 88-A, whose response-curve tolerance was ±3 dB from 70 to 9000 cycles. The amplifier was a composite three-channel broadcast remote type whose frequency response tested ±1 dB from 30 to 12,000 cycles. The headphones were the High Fidelity Model A-1 of the Brush Development Company, whose claimed range was 100 to 12,000 cycles.

12. If *E* altered the rate of his approach when he neared the wall, *S* would have used rate as a cue for his judgments. *E* had, therefore, to exercise care to walk uniformly. This, however, placed a heavy handicap on the *S*s in this experiment. In the preceding experiments, when the *S*s themselves did the walking, they were free (as the blind in everyday life) to shorten their steps or to decrease the rate as convenience dictated. That aid was in part, but only in part, provided them in this experiment. Ideal conditions would permit the *S*s to very the rate of the approach as they varied it in the other experiments when they themselves were doing the walking.

"FACIAL VISION": PERCEPTION OF OBSTACLES BY THE DEAF-BLIND*

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INTRODUCTION

Since Diderot first noted, in 1749, the "amazing ability" of a blind acquaintance to perceive obstacles and to judge accurately their distance (3), numerous experiments have been undertaken and theories advanced to explain the phenomenon. Not only are the blind who possess this ability unable to come to any agreement regarding the sensory basis of the phenomenon, but the experimenters have themselves been unable to solve the problem. Fact became entangled with theory and theory has all too often prejudiced the interpretation and report of the experimental results.[1]

It was against this background of fact and fiction that the studies on the perception of obstacles by the blind were begun in 1940 in the Cornell Psychological Laboratory. The experiments were undertaken without theoretical bias. The investigators had no theory to prove, hence they hoped to be able to follow without prejudice the lead of their experimental results.

The first of the Cornell studies on this topic was published in 1944 (see Supa, Cotzin, and Dallenbach, pp. 1-53). Because it contains a historical section, a general review of the earlier literature is omitted from this article, but that study itself must be reviewed here because the present investigation stems and follows on from it (see Supa, Cotzin, and Dallenbach, pp. 1-5; and references 14; 15, pp. 93-96; and 16).

In the 1944 study, four subjects (*S*s) were used: two blind students who possessed the ability to perceive obstacles at a distance, and two normally sighted graduate students in psychology who were able, after they had learned with blindfolds to perceive obstacles, to give sophisticated reports regarding their sensory experiences. All the *S*s served in seven series of experiments: three preliminary, Series 1 through 3; and four experimental, Series 4 through 7.

In the preliminary series (practice, exploratory, and normative), the blind *S*s became accustomed to the experimental condi-

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tions and the sighted *S*s learned to perceive obstacles when blindfolded. Every series was repeated twice: once, designated as Subseries A, with *S* wearing shoes and walking over the hardwood floor; and again, in Subseries B, with *S* walking in his stocking feet over a thick carpet runner. The *S*s were able, in the preliminary series, to perceive the obstacle placed in their paths and their performances - as measured by the ratios of their 'first perceptions' of the obstacle to the near approaches or 'final appraisals' of it - were superior in the A-series to their performances in the B-series. These results suggest that sound was a contributing factor in their perception of obstacles.

In the experimental series, Series 4 through 7, different sensory variables were in turn eliminated. In Series 4, *S*'s exposed surfaces were covered in order to eliminate cutaneous stimulation; hands by wool-lined leather gauntlets and face and head by a heavy felt curtain.

The *S*s were able under these conditions to perceive and to avoid the obstacle, but their performances were not as good as under normal conditions, the decrement being roughly of the order of the reduction in hearing caused by the blanket which covered head and ears. The conclusion drawn from the results of this series was that stimulation of the skin by reflected 'air waves' was *not a necessary* condition for the perception of obstacles. Whether it was a *sufficient* or *contributing* condition could not be answered from the results than at hand.

In the next series of experiments, Series 5, the *sufficiency* of cutaneous surfaces as well as the *necessity* of the aural mechanisms was investigated. *S*'s ears were stopped, with the result that hearing was reduced by about 65 dB, and all the areas of the skin, except the external auditory meatuses and tympanums, were open to stimulation by 'air-' and soundwaves reflected from the obstacle. If the cutaneous surfaces were *sufficient*, *S* should under these conditions perceive and avoid the obstacle; if aural stimulation was *necessary*, *S* should not be able to do so. All of the *S*s failed; they collied with obstacle in every one of 400 trials and not one of them was able to learn to perceive it under these conditions. Since the *S*s' heads, faces, arms, and hands were open to stimulation and their aural mechanisms were not, the results of this series suggest that the cutaneous surfaces were not *sufficient* for the perception and that the aural mechanisms were *necessary*.

These results could not, however, be considered as conclusive until it was shown in the following series of experiments, Series 6, that they were not due to intersensory dependence - that is, to the deleterious effect of the loss of hearing on cutaneous sensitivity (9, pp. 382-383; 31, p. 667). In Series 6, hearing was left functionally intact though not open to stimulation by the reflection of 'air-' and soundwaves from the obstacle. This condition was accomplished by means of a sound screen - earphones

carrying a 1000-cycle tone sounding at moderate intensity placed over *S*'s ears. His head, face, arms, and hands were open to stimulation and his hearing was functionally intact - he heard, though nothing other than the screening tone. Under these conditions, the *S*s ran into the obstacle in every one of 200 trials. They did not perceive it and they could not learn to do so. These results warrant, therefore, the acceptance of the conclusions tentatively drawn in Series 5 - namely, that aural stimulation by reflections from the obstacle was a *necessary* condition for the perception and that the exposed cutaneous surfaces were not *sufficient* conditions for it.

In the final series of experiments, Series 7, all stimulation except aural was eliminated. This was accomplished by placing *S* in a soundproof room and by having him judge the experimenter's (*E*'s) approach to an obstacle by means of the sounds of *E*'s footsteps which were picked up by a microphone, carried by *E* at ear-height, and transmitted to *S* through a high fidelity amplyfying set and earphones. All of the *S*s were able, under these conditions, to perceive *E*'s approach to the obstacle, and their ability to do so was but slightly inferior to their performances when they themselves walked toward the wall. The results of this series reaffirmed those of the other series and led to the general conclusion that the *S*s perceived obstacles by means of aural cues.

For the authors of that study to have concluded that their *S*s perceived obstacles by auditory cues would have been to transcend their results. In every one of their experiments, the *aural* mechanisms were either eliminated entirely or left intact; consequently it was impossible to determine whether stimulation of the cutaneous surfaces of the external ear (meatuses and tympanums), as James suggested (18, pp. 140 and 204-205), or audition was the *necessary* and *sufficient* condition. Decision concerning this point could be reached only by further experiments.

The groundwork was thus prepared by the 1944 study for a crucial experiment: the determination of the sensory basis of the 'obstacle sense' by the isolation and separate investigation of the aural components. Isolation might be accomplished in two ways: by eliminating the possibility of cutaneous sensation, leaving audition intact; and by eliminating audition, leaving the cutaneous surfaces open to stimulation.

The first set of conditions might be obtained by anesthetizing the skin of the external ear (meatuses and tympanums). Results obtained by this method, however, would be neither clean cut nor decisive. The success or failure of the *S*s to perceive obstacles under this set of conditions could not definitely be interpreted. If they succeeded, their success might not be due to audition but to incomplete anesthetization of the skin, because there is no ready way of determining with certainty the extent or completeness of the anesthetization of that area. If, on the

other hand, the *S*s failed, their failure might be due not to the loss of cutaneous sensitivity but to deleterious effects of the anesthetic upon the auditory mechanisms - the tympanums and ossicles. The interpretative dilemma, whatever the results, would cloud the issue and further work would have to be done. The crucial experiment is not to be made by this method.

The second set of conditions - the elimination of hearing, with the cutaneous surfaces of the meatuses and tympanums being left intact and open to stimulation - is present in the ears of the deaf. No anesthetics or drugs need to be used with them. Either seeing-deaf or blind-deaf persons, if they are without external ear defects, meet these conditions equally well, but the nature and outcome of the experiments will vary greatly accordingly as *S*s are drawn from the seeing or the blind group.

If seeing-deaf persons were used as *S*s, since they are dependent in everyday life upon vision for their perception of obstacles, the investigation would resolve itself into a learning experiment - into determining whether they could learn without vision to perceive obstacles at a distance. While that study would be interesting, the results would be decisive only if they were positive - that is, if the seeing-deaf *S*s learned. If, however, the results were negative - that is, if the *S*s could not learn - then we should again have an interpretative dilemma on our hands because several explanations, in addition to the lack of hearing, might with equal cogency be advanced for their failure. For example, the inability of the seeing-deaf to learn might be due (1) to timidity - the deaf are excessively timid, particularly when blindfolded; (2) to want of incentive - they would not be bettering their lot by acquiring an ability that they would not afterward use; or (3) to lack of the special ability - only a small percentage of the blind possess the ability, thought by many to be a special talent (16, p. 50). Results with seeing-deaf *S*s would, therefore, be crucial only if they were positive; only if stimulation of the external ears was found to be the *necessary* and *sufficient* condition of the perception. Negative results would not be determinant.

If, on the other hand, blind-deaf persons were used as the *S*s, they would have to be chosen with special care. A haphazard selection, sought in most experiments, would not be desirable here. Most of those suffering this double handicap lead a passive and vegetative existence. They are closely confined in their movements and feel their way around with their hands even in their home environments. (Helen Keller "gropes her way without much certainty in rooms where she is quite familiar" [20, p. 291].) They must be led whenever they leave their familiar surroundings. These persons do not possess the 'obstacle sense' and they give no indication, even after many years, of being able to acquire it. Experiments with *S*s of this type, therefore, would be of little value or point because they are 'loaded' in

favor of negative results - hence of the audition theory.

There is, however, a small percentage of the deaf-blind who think they possess the 'obstacle sense' - or behave as though they did. They seem to be specially endowed as they move freely about their environments and do not hesitate to travel alone by bus and train to new places. If persons of this type - 'mobile' blind-deaf - were selected as *S*s, the results, whether positive or negative, would be unambiguous and conclusive.

If it turned out that they possessed the ability, the pressure theory would be completely vindicated. If, however, it turned out that they did not, then learning experiments could with profit be undertaken to discover whether they could acquire it. The limitations of the learning experiments with the seeing-deaf would not apply to the 'mobile' blind-deaf. Results, whether positive or negative, would lead to definite conclusions. If positive, if they were able to learn to 'perceive obstacles,' the pressure theory would be vindicated; if negative, if they were unable to learn, the auditory theory would be substantiated.

Negative results, ambiguous in the case of the seeing-deaf *S*s, would not be ambiguous with the 'mobile' blind-deaf, because "lack of audition" is the only one of the several explanations applying to the seeing-deaf *S*s that would apply to them. Their failure to learn (if they failed) could not be due, as in the case of the seeing-deaf, to timidity. They are not timid but, on the contrary, are venturesome to a high degree; it takes tremendous courage to go alone outside the home environment when both blind and deaf. Their failure to learn could not be due to want of incentive. They would greatly better their lot if they acquired the ability, hence they would certainly be highly motivated. Neither could their failure be due to lack of the special endowment. If any among the deaf-blind possess the special endowment, surely these *S*s, who stand out so prominently among their confreres, must possess it; at least they possess something that the great majority of the deaf-blind do not. The only reason, therefore, that these 'mobile' deaf-blind *S*s would fail to learn would be because of their deafness.

The crucial experiment, its method, procedure, and type of *S* required, is indicated.

PROBLEM

The problem of the present study is to determine whether the aural mechanisms shown in 1944 to be the basis of the 'obstacle sense' are auditory or cutaneous or whether both are involved. In order that the results would be unambiguous and decisive, the second method of attacking the problem described previously (eliminating audition, leaving the cutaneous surfaces of the meatuses and tympanums open to stimulation by 'air-' and soundwaves) was used; and deaf-blind *S*s were selected who claimed to possess the

'obstacle sense' or behaved as if they did.

SUBJECTS

Arrangements were made with 20 deaf-blind people to serve in the study. Due, however, to accidents and other exigencies, only half of these (2 women and 8 men) participated in the experiments. Those who served as *S*s were:

David Badger (*DB*), Torresdale, Pennsylvania
Francis W. Bates (*FB*), Millersburg, Pennsylvania
George Gilmour (*GG*), Brooklyn, New York
John Gilmour (*JG*), Brooklyn, New York
Eva Hall (*EH*), Cincinnati, Ohio
Harris Levine (*HL*), Torresdale, Pennsylvania
Lawrence Moody (*LM*), Binghamton, New York
Douglas Richards (*DR*), Newark, New Jersey
Chester Roberts (*CR*), Cambridge, Massachusetts
Marian Stilwell (*MS*), Mohawk, New York

These *S*s, to whom our thanks are due because they contributed their services and gave so unsparingly of their time and effort, were selected because of their ability to get about alone.[2] Although only one of them, *FB*, thought he possessed the 'obstacle sense' - the phrase had no meaning to the others - all of them behave in every day life as if they did. They not only move freely about their home environments, but they unhesitatingly travel alone by train and bus as occasion requires;[3] and those gainfully employed (*FB*, *GG*, *JG*, *EH*, *LM*, and *CR*), go daily alone to and from their work.

The *S*s reported at Ithaca during July and August, 1946, in groups of two to four. About 10 days were required to complete the experiments with them. The experiments were conducted at three periods of the day: in the morning from 9 to 12, in the afternoon from 2 to 5, and in the evening from 7 to 10. None of the *S*s, however, served at more than two periods during a single day, and these experimental hours were so distributed that they occurred equally often at each of the three work periods. During the off periods, the *S*s' case histories were taken,[4] their eyes were examined by an oculist, and their ears by an aurist, audiograms were made of their hearing by both air and bone conduction, and their vestibular sensitivity was tested by measuring the time they could stand on one foot and also by means of a rotation chair.[5] For the purposes of this study, it was imperative that the extent and degree of the *S*s' blindness and deafness be precisely known.

The case histories, reports from the medical examiners, and the test results are given below for every *S*.

DB

Age: 50 years

History: Congenitally deaf. Became blind about 24 years of age as a result of injury to one eye and sympathetic ophthalmia in other eye. Is mute, rarely makes a sound. Communicates by writing simple sentences and by the manual and sign language. Reads palm printing readily, and reads and writes braille, Grade 2. Worked at manual labor until blinded on father's farm. Attended school for 6 years at Western Pennsylvania School for the Deaf, Pittsburgh, Pennsylvania. Now lives at the Home for the Deaf, Torresdale, Pennsylvania. Is a skilled horticulturist and has a sizable plot assigned him for a flower garden. Has had displays at the Philadelphia Flower Show.

Examination: Eyes: O. U., optic atrophy; no light perception. Ears: Tympanic membrane in each ear very thin and retracted; meatuses normal.

Tests: Audiometric: No hearing up to 120 dB in either ear by air or bone conduction. Standing: Stood on either foot for 30 to 40 sec - performance normal. Rotating chair: Vertigo; nystagmus, after-sensation of movement, and strong compensatory reactions - experience and performance normal.

FB

Age: 55 years

History: Was born normal, became deaf and blind during infancy. Has worn hearing aids of various types for years; changes aids as improvements are made; now uses a vacuum-tube set. Speaks clearly and fluently; diction excellent. Received education at Perkins Institute for the Blind at Boston, Massachusetts. Is an expert at reading and writing braille. Claims to be able to read braille faster than any person he has ever met - and his contacts have been many. Uses typewriter and braillewriter with great speed. Reads palm printing and uses the manual alphabet but is not particularly adept in either because of the lack of practice. Travels widely by himself. Has been a news reporter, a teacher of the blind, and is now Director of the American League for the Deaf-Blind, Millersburg, Pennsylvania.

Examination: Eyes: O. S., removed. O. D., dense opacities covering entire cornea with small epithelial bullae. Unable to view iris or fundus due to dense lesion of cornea. Tension normal. Vision: light and

color perception, and hand movements against bright background. History of ophthalmia neonatorum and also, 12 years ago, of dislocated lens. No surgery at any time. Ears: Meatuses and tympanums normal.

Tests: Audiometric: Right ear: Air or bone conduction, no hearing up to 120 dB. Left ear: Bone conduction, no hearing up to 120 dB. Air conduction, without hearing aid, hears from 128 to 2896 Hz at 60 to 90 dB (see audiogram, Figure 1); with hearing aid, hears from 64 to 2896 Hz at 50 to 70 dB (see audiogram, Figure 2). Standing: On either foot, 1 to 3 sec. Rotating chair: No vertigo, nystagmus, after-sensation of movement, nor compensatory reactions.

GG

Age: 55 years

History: Congenitally deaf. Of seven siblings, he and two sisters were born deaf. Is mute; makes sounds that are not recognizable but can pronounce names of his brothers and sisters. Became blind gradually in his early twenties. Uses the manual alphabet, reads palm printing, and also braille though slowly. Works in the Brooklyn Industrial Shop for the Blind making brooms. His brother, *JG*, and he traveled to and from Ithaca alone by railroad.

Examination: Eyes: O. S., light perception. O. D., no light perception. Marked opacity in both lenses. Fundi not visible. Complicated cataract in both eyes. Ears: Tympanic membrane and meatuses normal in appearance.

Tests: Audiometric: No hearing up to 120 dB by bone conduction in either ear, and none by air conduction in the right ear. With air conduction and intensity of 70 dB (see audiogram, Figure 3), two tonal islands at 128 Hz and 4096 Hz in left ear. Standing: On either foot, 1 to 2 sec. Rotating chair: No vertigo, nystagmus, after-sensation of movement, nor compensatory reactions.

JG

Age: 46 years

History: Became deaf during infancy following scarlet fever. Is mute, tries to talk but makes few sounds other than "thank you" that are recognizable. Became blind gradually in his early twenties. Uses manual alphabet; reads palm printing and braille slowly. Works in the Brooklyn Industrial Shop for the Blind in general work.

His brother, *GG*, and he traveled to and from Ithaca alone by railroad.

Examination: Eyes: O. U. 20/200; oscillate as in congenitally blind; opacity in posterior lens capsule. Very high myopia. Not possible to study fundi in detail due to constant eye movement. Ears: Tympanic membranes of both ears normal in appearance except for lack of normal luster. Meatuses normal.

Tests: Audiometric: No hearing by bone conduction in either ear nor by air conduction in left ear up to 120 dB. By air conduction in right ear; hears from 64 to 4096 Hz at 65 to 90 dB (see audiogram, Figure 4). Standing: On either foot, 1 to 2 sec. Rotating chair: No vertigo, nystagmus, after-sensation of movement, nor compensatory reactions.

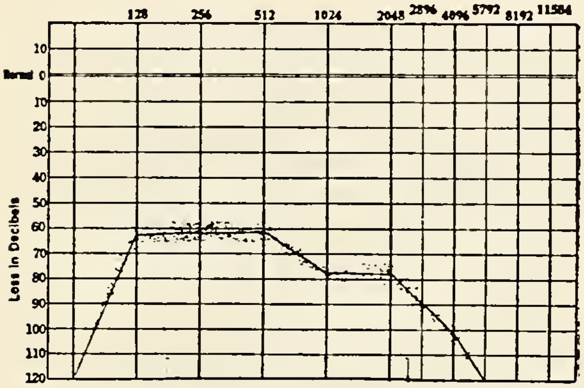

Figure 1. FB: *Left Ear Without Hearing Aid.*

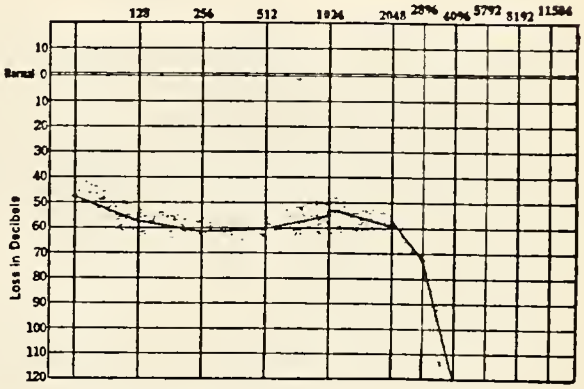

Figure 2. *FB: Left Ear with Hearing Aid.*

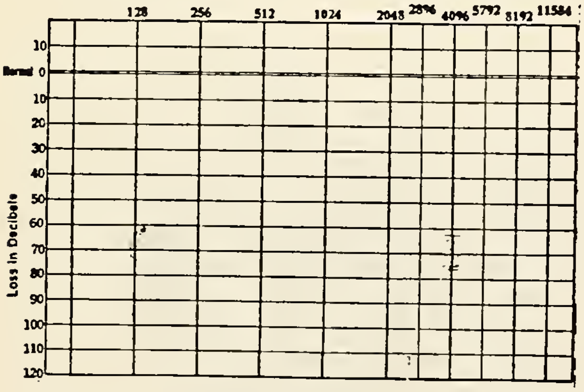

Figure 3. GG: *Left Ear Showing Tonal Islands.*

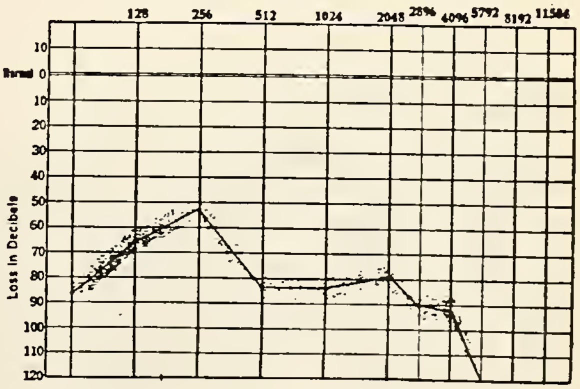

Figure 4. JG: *Right Ear.*

Note: Shaded area shows zone of just noticeable and just not noticeable tone; the line is the average of those two values.

EH

Age: 42 years

History: Lost vision and hearing gradually; vision between 8 to 10 years of age and hearing between 14 and 15. Attended public schools for three years. Can write and speaks well. Speech distinct, but very faint unless continually requested to speak louder. Is highly efficient at reading palm printing and in using and understanding the manual and sign language. Attended the Ohio State School for the Blind from 11 to 14 years of age, the Ohio State School for the Deaf from 14 to 15 years, and the St. Rita School for the Deaf at Cincinnati from 15 to 18 years of age. Finished the ninth grade. Reads braille, Grade 2 standard, rapidly. Came to Ithaca from Cincinnati, Ohio, by bus - a 28 hour trip - and returned home by airplane, her first air trip and one eagerly anticipated.

Examination: Eyes: O. D., removed in 1928 at age of 23 years. O. S., central dense corneal opacities deep in stroma with considerable vascularization, typical of old interstitial keratitis. Small immobile pupil with post synechiae. Peripheral iridotomy at eight o'clock. Visible lens surface is partly covered with pigment deposits. Unable to visualize the fundus. Tension normal to fingers. Light perception with projection. Ears: Tympanums and meatuses normal.

Tests: Audiometric: No hearing by bone or air conduction in either ear up to 120 dB. Standing: On either foot, 1 to 2 sec. Rotating chair: No vertigo, nystagmus, aftersensation of movement, nor compensatory reactions.

HL

Age: 49 years

History: Congenitally deaf - of four siblings he and two sisters were born deaf. Became blind at 24 years of age. Is mute, rarely attempts to speak but in excitement makes gutteral sounds. Lost vision gradually. Attended school for 11 years at the Central Institute for the Deaf at Rome, New York. Writes simple sentences, reads palm printing and reads and writes braille, Grade 2; uses manual and sign language. Is expert in handicrafts, caning chairs, and basketry. Lives at the Home for the Deaf, Torresdale, Pennsylvania.

Examination: Eyes: O. U., no light perception, no pupillary reflex. Diagnosis: chronic choroiditis. Ears: No abormalities noted.

Tests: Audiometric: No hearing by air or bone conduction in either ear up to 120 dB. Standing: On either foot 1 to 2 sec. Rotating chair: No vertigo, nystagmus, after-sensation of movement, nor compensatory reactions.

LM

Age: 45 years

History: Suffered spinal meningitis at age of 1 year and deafness soon followed. Became totally blind, after years of failing vision, at 42 years of age from retinitis. Is mute, rarely utters a sound. Attended Clark School for the Deaf, Northampton, Massachusetts, for 10 years and the American School for the Deaf, Hartford, Connecticut, for 4 years. Finished eleventh grade. Reads and writes braille rapidly; reads palm printing rapidly; and uses manual and sign language. Is self-supporting; works on machine parts in shop for the blind in Binghamton, New York.

Examination: Eyes: O. U., no light perception; pupils immobile, mid-dilated; cornea and lense clear; a few large vitreous floaters; pigment clumping in typical bone corpuscle formation; disks atrophic; retinal vessels markedly attenuated. Diagnosis; retinitis pigmentosa. Ears: Normal.

Tests: Audiometric: No hearing by air or bone conduction in either ear up to 120 dB. Standing: On either foot, 1 to 3 sec. Rotating chair: No vertigo, nystagmus, after-sensation of movement, nor compensatory reactions.

CR

Age: 48 years

History: Normal child; attended public school until 9 years of age, when both sight and hearing began to fail. Then attended the Perkins Institute for the Blind at Boston, Massachusetts, for 6 years. Speaks fairly well but without modulation; however, can readily be understood. Reads and writes braille expertly and is adept at reading palm printing. Is facile in the use of the manual language. Employed in a workshop for the blind in Cambridge, Massachusetts, where he makes brooms. Came from Boston to Ithaca and returned home by himself.

Examination: Eyes: O. D., removed. O. S., prominent eyeball; conjunctiva and lid normal; tension normal to fingers. Slit-lamp: dense central corneal opacities involving stroma; infiltration superiorly at site or iridectomy and cataract extraction. Iris atrophic and pulled up superiorly

leaving a very small opening at upper margin; unable to visualize fundus; trans-illumination normal. Vision limited to light perception with normal projection. Ears: No observed abnormalities.

Tests: Audiometric: No hearing by air or bone conduction in either ear up to 120 dB. Standing: On either foot, 1 to 2 sec. Rotating chair: No vertigo, nystagmus, after-sensation of movement, nor compensatory reactions.

DR

Age: 35 years

History: Became deaf at 1 year of age, following whooping cough. Is mute and utters few sounds. Blindness congenital. Attended school for the deaf at Trenton, New Jersey. Reads and writes braille slowly. Adept with manual and sign language.

Examination: Eyes: O. U., pupils react very slightly to light; media clear; fundi show considerable pigmentary degeneration with clumping in typical bone-corpuscle formation; optic atrophy with moderate attenuation of vessels. Light perception but can hardly count fingers at 1 ft. Diagnosis; retinitis pigmentosa. Ears: Normal.

Tests: Audiometric: No hearing by air or bone conduction in either ear up to 120 dB. Standing: On either foot, 1 to 3 sec. Rotating chair: No vertigo, nystagmus, after-sensation of movement, nor compensatory reactions.

MS

Age: 34 years

History: Lost vision at age of 4 years after a case of measles and infantile paralysis. Became deaf gradually at 16 years of age. Wears hearing aid - carbon set which is preferred to modern sets of vacuum-tube type. Speaks clearly and is easily understood. Attended New York School for the Blind at Batavia, New York, for 9 years. Reads and writes braille, Grades 1-1/2 and 2, rapidly. Does not use or understand the manual alphabet or sign language. Is adept at handicrafts.

Examination: Eyes: O. U., have dense mottled central corneal opacities involving the whole stroma with numerous old blood vessels suggestive of old interstitial keratitis; pupils mid-dilated, no reaction to light; post-polar cataract; disks strophic with diminished size of blood vessels. No light perception. Ears: Tympanums and meatuses normal.

Tests: Audiometric: Bone conduction: no hearing in either ear up to 120 dB. Air conduction: left ear, hears from 64 to 5792 Hz at 20 to 60 dB with hearing aid, and at 50 to 90 dB without hearing aid (see audiogram, Figure 5); right ear, hears from 128 to 2896 Hz at 35 to 70 dB with hearing aid, and at 65 to 100 dB without hearing aid (see audiogram, Figure 6). Standing: On either foot, 1 to 2 sec. Rotating chair: No vertigo, nystagmus, after-sensation of movement, nor compensatory reactions.

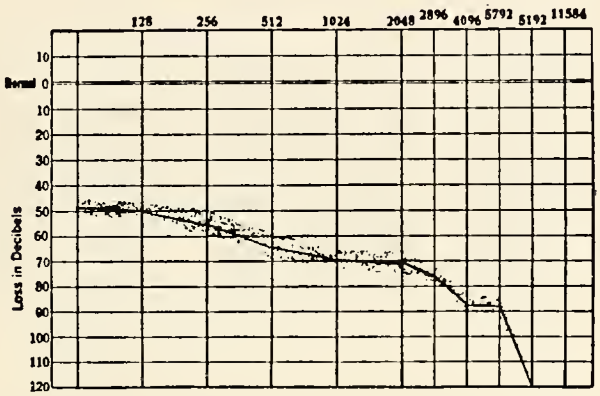

Figure 5. MS: Left Ear.

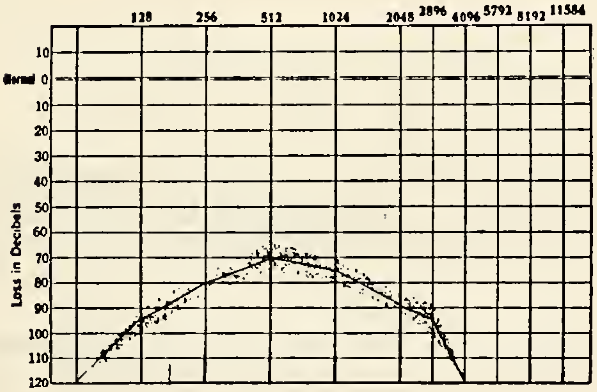

Figure 6. MS: Right Ear.

A summary of the conditions affecting the *S*s is given in Table I. This table shows that the ages of the *S*s varied from 34 to 55 years; and that 2 were in their middle thirties, 5 in their forties, and 3 in their fifties. Their ages were perhaps a bit unfavorable for our purposes but independence of movement, the primary basis of their selection, was more important than age.

Six of the *S*s were mute. Of the 4 that could talk, 2 could hear well enough with the assistance of hearing aids to carry on conversations.

Three of the *S*s were congenitally deaf, 4 became deaf during infancy, and 3 during late childhood. Blindness on the whole occurred later in life than deafness; only 2 of the *S*s lost their vi-

TABLE I

SUMMARY OF THE FINDINGS REGARDING THE PHYSICAL CONDITIONS OF THE *S*s

S	Age (in yr.)	Speech ability	Handicap: blindness	Handicap: deafness	Effect of handicap: Vision* L	Vision* R	Audition† Bone conduction L	Bone conduction R	Air conduction L	Air conduction R	Vestibular sensitivity	Condition external ears
(1) *DB*	50	mute	24 yr.	congenital	none	none	none	none	none	none	normal	normal
(2) *FB*	55	excellent	infancy	infancy	removed	l.p., c.p.	none	none	128–2896~	none	none	normal
(3) *GG*	55	mute	early 20s	congenital	l.p.	none	none	none	islands	none	none	normal
(4) *JG*	46	mute	early 20s	infancy	20/200	20/200	none	none	none	64–4096~	none	l.l.‡
(5) *EH*	42	faint	8–10 yr.	14–15 yr.	l.p.	removed	none	none	none	none	none	normal
(6) *HL*	49	mute	24 yr.	congenital	none	none	none	none	none	none	none	normal
(7) *LM*	45	mute	30–42 yr.	1 yr.	none	none	none	none	none	none	none	normal
(8) *CR*	48	fair	9–10 yr.	9–10 yr.	l.p.	removed	none	none	none	none	none	normal
(9) *DR*	35	mute	congenital	1 yr.	l.p.	l.p.	none	none	none	none	none	normal
(10) *MS*	34	good	4 yr.	16 yr.	none	none	none	none	64–5792~	128–2896~	none	normal

* l.p.=light perception; c.p.=color perception.
† Where "none" appears, it means none up to 120 db.
‡ Tympanum lacks normal luster.

sion earlier than their hearing. Of our *S*s, 1 was congenitally blind, 1 became blind during infancy, 1 during early childhood, 2 during late childhood, 4 during their early twenties, and 1 after he was thirty years of age.

Four of the *S*s had no vision in either eye and, of these, 3 could not hear with either ear by air or bone conduction up to 120 dB. Seven *S*s had no vision in their right eyes and 5 had none in their left eyes. Five *S*s had light vision in one or the other eye (1 in both, 3 in the left only, and 1 in the right only) and 1 had 20/200 vision in both eyes.

None of the *S*s could hear by bone conduction with either ear up to 120 dB intensification - the limits of our audiometer. Six of the *S*s could not hear by air conduction with either ear within the same intensive limits. Of the 4 possessing some degree of hearing, 2 were totally deaf in their right ears up to 120 dB, and 1 of these, *GG*, had only two narrowly limited total islands in his left ear. Only 1 *S* (*MS*) had some degree of hearing to air conduction in both ears. The auditory ranges of these *S*s were greatly curtailed - chiefly among the upper frequencies - and, within the range of frequencies heard, the intensity had greatly to be increased.

With one exception, all of the *S*s lacked the vestibular functions: they could not stand on one foot and, when rotated, they neither experienced the usual subjective phenomena nor exhibited the behavior normally accompanying semicircular stimulation. The *S* excepted, *DB*, could stand on one foot as long as a normal individual and he exhibited and reported all the phenomena usual to rotation. He was, as it will be recalled, congenitally deaf.

The outer ears, the meatuses and tympanums, of all the *S*s were normal. If these tissues are capable of being stimulated by 'air-' and soundwaves, they would be stimulated in these *S*s.

It appears from the records of the examinations and tests given these *S*s that they were well selected. They possessed the precise collocation of physical characteristics and other conditions necessary for a crucial study.

THE EXPERIMENTS

Experiment 1

The first experiment was exploratory and devoted to learning. It was designed to acquaint the *S*s with laboratory conditions, as opposed to the conditions of everyday life, and to ascertain whether they - the pick of the deaf-blind within a 300-mile radius of Ithaca, New York, insofar as ability to move about independently was concerned - possessed the 'obstacle sense,' that is, whether they could, by means of the cutaneous surfaces of their meatuses and tympanums, perceive and approach closely the end wall of a large room. When they demonstrated that they could not, the experiment became a study in learning, the purpose of which was to determine whether *S*s, endowed with the courage to leave the narrow confines usual to the deaf-blind, could learn 'to perceive obstacles' when their aural equipment was limited to cutaneous sensitivity.

Procedure

In this experiment, a repetition of Series 1 A of the earlier study *S* walked with shoes on over a bare hardwood floor, between two carpet runners, 30 in. apart, toward the end of the experimental room - a large hall 18 ft wide, 61 ft long, and 20 ft high with beamed, center-ridged ceiling and two skylights. The end wall, the obstacle, was stone, 4 ft thick, hard plastered, and decorated with semigloss paint. Its coefficient of reflection was consequently high; hence it was particularly favorable to the perception and avantageous to the *S*s.

After receiving instructions regarding what he should do, *S* was blindfolded, led about the hall, and then placed at the start-

ing point. He was blindfolded to eliminate any light sensitivity that he may have had and also, incidentally, to reduce the facial area open to cutaneous stimulation by an amount similar to that in the early study in which blindfolded, normal sighted *S*s were used. A small pad of cotton wool was placed over each eyeball; and then the snugly fitting blindfold was put in place. *S* was then led about the hall to disorient him so he would not know where the starting point was relative to the end wall.

Six different starting points, 6, 12, 18, 24, 30, and 36 ft from the wall, were used. None of the *S*s knew what these distances were. They were selected in turn by planned haphazard choice which guaranteed that every point would be used as often as every other and without fixed sequences.

After his disorientation, *S* was placed at the designated starting point facing the wall. At a tap on the back he walked toward the wall, down the path between the carpet runners. When he perceived the wall ('first perception'), he stopped and raised his right arm. On being tapped again, he continued and approached the wall as closely as he could without touching it ('final appraisal'), when he raised his left arm. The distances from the wall at which he raised his arms were measured to the nearest 6 in. from markings on the floor, and the ratio (p/a) of his 'first perception' (p) to his 'final appraisal' (a) was taken, if he had not touched the wall, as the measure of his performance.

In none of the trials was *S* stopped from hitting the wall. The punishment of the collisions was, as in every day life, an incentive to performance.

The work of an experimental hour was a series of 50 trials. The trials were, however, frequently interrupted. Whenever an *S* gave the least indication of being weary, he was given a rest. This procedure was followed because the ability to detect obstacles was shown by Dolanski to be markedly influenced by fatigue and distraction (5, 6). We wished our *S*s to be at their best and to do their best in the experiments of this study.

The following instructions, written in braille, were given the *S*s to read and study as they reported at the Laboratory and thereafter at the beginning of every experimental hour.[6]

> "A blindfold will be placed over your eyes so you will not have more skin showing than sighted people who also do this experiment.
>
> "After you are blindfolded, you will be led about the hall in order that you will not know how far you are away from the end wall. After a short time you will be placed facing the wall. When

you are tapped on the back, walk forward to the wall. When you think the wall is in front of you, raise your right arm. After being tapped again, lower your arm and continue to walk to the wall. Approach it as closely as possible without touching it. When you have done that, raise your left arm and stand still. You will be walked about again and another trial will be made.

"You will be started from different distances from the wall at the different trials. Walk on the floor and stay between the two carpet runners. If you touch the carpet you are off the track. You will be asked to do this experiment over and over again until we know how well you can do it."

After *S* had studied the instructions, he was examined regarding them to see if he understood them and knew what was expected of him.[7] If he did, the trials were then begun; if he did not, or was a bit confused about what he was to do, the following supplementary instructions, written also in braille, were given him.

"What we are trying to do is to see if you know that an obstacle is in front of you before you run into it.

"The obstacle in this study is the end wall of the hall. You will be blindfolded so you will not have any advantage over the sighted people who also do this experiment. We wish to cover as much of the skin on your face as we do on theirs.

"Now this is what you are to do: When the signal - a tap on the back - is given you, walk toward the wall and stay between the carpet runners. When you think the wall is in front of you, stop and raise your right arm. When the examiner taps you on the back again, go on again toward the wall.

"When you think you have reached the wall, stop and raise your left arm. Do not touch the wall with your foot or any other part of your body, but get as close to it as you can."

After the supplementary instructions - required only by 4 of the *S*s - had been read and studied, *S* was again examined, as before, to see if he now knew what he was to do.

From their answers to the questions about the instructions

and their behavior during the subsequent experiments, we are satisfied that all of our *S*s understood the purpose of the experiment and what was required of them.

Only 9 of the 10 *S*s were used in Experiment 1. *FB* did not participate in it because he had demonstrated in similar experiments performed with him during the summers of 1941 and 1942 (the results are combined and given in Table II) that he could detect and avoid running into the end wall of the hall. A few trials with him during the present experiments sufficed to show that he still possessed that ability. Experiment 1 was not designed to discover how his performances were accomplished. It would, therefore, have been a useless expenditure of time to have conducted the trials with him. His results will be considered separately after those with the other *S*s are reported.

As soon became apparent, after a few trials, none of the *S*s gave any evidence of possessing the 'obstacle sense.' All collided with the wall frequently before reporting the 'first perception,' and the trials in which they did not were 'guesses,' as they themselves reported and as the objective results clearly indicated. The few 'final appraisals' made were also, by their own report and by the objective results, sheer guesses. The experiment became, therefore, a study in learning, the object of which was to determine whether these *S*s could acquire the ability to perceive obstacles.

Although we did not know specifically what to teach the *S*s, we did know that our objective conditions were highly favorable to the perception of obstacles and that learning would be greatly facilitated (if it were possible for them to learn) by the employment of various aids and incentives that had been avoided in the trials undertaken to determine whether they possessed the ability. In the subsequent trials in Experiment 1, the following rules of procedure were, therefore, adopted.

1. *S* was allowed to collide with the wall - that is, punishment.

2. Whenever *S*'s 'final appraisals' were within 3 ft of the wall, he was praised for his performance by patting him on his back and by palm printing "good" on one of his hands - that is, reward.

3. Whenever *S*'s 'final appraisals' were more than 3 ft from the wall, praise was omitted - that is, withholding reward.

4. After every 'final appraisal,' *S* was led to the wall; thus he knew the amount of his error after every trial - that is, knowledge of results.

5. *S* was led between successive trials through only a few turns about the hall - that is, avoidance of fatigue.

6. *S* was given frequent rests during the trials (50) of an experimental hour - that is, avoidance of fatigue and of ennui.

7. *S* was frequently informed during the later part of an experimental hour how many trials were still to be made - that is, knowledge of task incompleted.

Under the conditions and procedures described above, the *S*s were given 50 trials at every one of the 6 starting points - a total of 300 trials for every *S*.

Results

Objective

The results of Experiment 1 appear in Table II, which gives for every *S* and every starting point, the average distance of the 'first perceptions' and 'final appraisals,' the ratios of performance, and the number of collisions with the wall, divided accordingly as they occurred before or after the 'first perceptions.'

'First Perceptions': The general averages of our *S*s' 'first perceptions' are high: *DB*'s is 11.84 ± 5.08 ft; *GG*'s, 14.26 ± 9.79 ft; *JG*'s, 13.91 ± 6.63 ft; *EH*'s, 12.34 ± 6.78 ft; *HL*'s, 14.93 ± 7.46 ft, and so on. They exceed the general averages (6.36 ± 0.64 ft; 2.12 ± 0.80 ft; and 0.98 ± 0.66 ft) of three *S*s in the earlier study (see Supa, Cotzin, and Dallenbach, p. 11), who demonstrated under identical conditions that they possessed the 'obstacle sense.' Considered alone, these results would indicate that our *S*s possess the 'sense' in a high degree. The standard deviations of their averages, however, are extremely large, running in most cases to more than 50 percent.

The excessive variability of the 'first perceptions' led us to fractionate the data and compute the averages of the *S*s for the different starting points. These averages (see Table II) show a very different picture. They increase for all our *S*s with the distance of the starting points - that is, the further the starting distance the larger the averages. For example, *DB*'s averages at the different starting points are 3.49 at 6 ft; 6.95 at 12 ft; 9.50 at 18 ft; 13.49 at 24 ft; 16.25 at 30 ft; and 19.75 at 36 ft. These results stand in striking contrast to those obtained in the earlier study, in which the average at one starting point was representative of the averages at every other point (see Supa, Cotzin, and Dallenbach, pp. 12-13), and they indicate that the determining factor in our *S*s' reports was not their perception of the wall but the distance of the starting points from the wall.

Sheer chance within the limitations set by the distances of

TABLE II

RESULTS OF EXPERIMENT 1

Average Distance and Variation (in Ft) of the 'First Perception' and 'Final Appraisal,' the Performance Ratios, and the Number of Times the *S*s Ran into the Wall, for Every Starting Position.

S	Report	Starting distances from wall (in ft.)						General average	Collisions	
		6	12	18	24	30	36		No.	%
(1) *DB*	First perception (p)	3.49	6.95	9.50	13.49	16.85	19.75	11.84	7	2
		± .74	±1.59	±2.25	±2.59	±2.34	±2.87	±5.08		
	Final appraisal (a)	1.13	3.54	4.37	4.41	4.73	5.71	4.17	72	24
		± .59	±1.90	±1.85	±2.05	±2.56	±4.14	±2.55		
	Ratio (p/a)	3.09:1	1.96:1	2.17:1	3.06:1	3.56:1	3.46:1	2.83:1		
	Collisions								79	26
	before (p)	5	0	2	0	0	0			
	after (p)	17	12	18	11	10	4			
(2) *FB*	First perception (p)	1.03	1.06	1.06	1.03	1.09	1.03	1.05	0	0
		± .23	± .27	± .31	± .28	± .24	± .32	± .14		
	Collisions	0	0	0	0	0	0	0	0	0
(3) *GG*	First perception (p)	3.38	5.29	9.66	15.10	19.68	22.94	14.26	44	15
		±1.22	±1.84	±1.70	±2.56	±3.23	±2.70	±9.79		
	Final appraisal (a)	1.30	3.04	3.50	5.20	6.81	7.23	5.64	95	31
		± .48	±1.06	±2.32	±2.28	±3.61	±2.90	±3.02		
	Ratio (p/a)	2.60:1	1.74:1	2.76:1	2.90:1	2.89:1	3.17:1	2.53:1		
	Collisions								139	46
	before (p)	42	2	0	0	0	0			
	after (p)	3	35	28	14	10	5			
(4) *JG*	First perception (p)	3.06	7.47	11.30	16.30	20.26	23.43	13.91	8	3
		± .98	±1.78	±1.98	±2.63	±2.55	±3.04	±6.63		
	Final appraisal (a)	1.07	3.37	4.92	6.78	6.75	8.00	5.46	148	49
		± .26	±1.77	±2.15	±3.11	±4.19	±6.58	±3.67		
	Ratio (p/a)	2.86:1	2.21:1	2.09:1	2.40:1	3.00:1	2.93:1	2.55:1		
	Collisions								156	52
	before (p)	7	1	0	0	0	0			
	after (p)	29	19	31	17	26	26			
(5) CR	First perception (p)	1.64	3.79	4.47	4.91	5.89	7.65	4.67	56	19
		± .77	±1.37	±1.60	±1.91	±2.69	±4.20	±1.95		
	Final appraisal (a)	1.29	2.98	2.50	2.80	3.08	4.61	3.09	70	23
		± .80	±1.54	±1.28	±1.58	±1.76	±3.43	±1.96		
	Ratio (p/a)	1.27:1	1.27:1	1.79:1	1.75:1	1.91:1	1.66:1	1.57:1		
	Collisions								126	42
	before (p)	25	8	12	6	3	2			
	after (p)	8	17	13	12	10	10			
(6) *DR*	First perception (p)	1.90	4.20	5.70	8.07	10.36	12.54	7.59	33	11
		± .75	±1.70	±2.31	±3.10	±3.23	±4.19	±4.10		
	Final appraisal (a)	1.44	2.13	2.31	3.90	4.82	5.51	3.99	110	37
		± .68	±1.51	±1.38	±2.31	±2.45	±2.85	±2.44		
	Ratio (p/a)	1.32:1	1.97:1	2.47:1	2.07:1	2.15:1	2.28:1	1.90:1		
	Collisions								143	48
	before (p)	20	6	3	4	0	0			
	after (p)	22	29	20	17	14	8			
(7) MS	First perception (p)	2.26	3.68	4.57	5.36	10.08	11.15	6.49	29	10
		± .89	±1.28	±1.14	±1.59	±7.11	±7.19	±3.98		
	Final appraisal (a)	1.06	1.82	1.90	2.22	3.30	5.43	3.00	81	27
		± .23	± .83	± .91	±1.36	±2.65	±5.00	±2.20		
	Ratio (p/a)	2.13:1	2.02:1	2.41:1	2.41:1	3.05:1	2.05:1	2.16:1		
	Collisions								110	37
	before (p)	15	8	4	0	0	2			
	after (a)	27	24	3	12	8	7			
(8) *EH*	First perception (p)	0	1.86	4.18	8.39	14.40	19.65	12.34	102	34
			±1.22	±1.74	±2.30	±3.08	±2.91	±6.78		
	Final appraisal (a)	0	0	1.19	2.87	7.50	13.60	8.21	68	23
				± .66	±1.75	±1.95	±2.79	±4.61		
	Ratio (p/a)	—	—	3.51:1	2.92:1	1.92:1	1.44:1	1.50:1		
	Collisions								170	57
	before (p)	50	43	5	1	2	1			
	after (p)	0	7	37	18	4	2			

TABLE II - (continued)

S	Report	Starting distances from wall (in ft.) 6	12	18	24	30	36	General average	Collisions No.	%
(9) *HL*	First perception (p)	2.79 ± .91	7.02 ±1.28	12.20 ±1.44	17.78 ±1.02	22.16 ±2.68	26.83 ±1.74	14.93 ±7.46	11	4
	Final appraisal (a)	.89 ± .26	2.29 ± .95	4.54 ±2.56	5.46 ±2.18	4.31 ±2.94	6.57 ±4.67	4.72 ±3.12	146	48
	Ratio (p/a)	3.13:1	3.07:1	2.69:1	3.26:1	5.14:1	4.08:1	3.16:1		
	Collisions								157	52
	before (p)	3	4	1	0	1	2			
	after (p)	38	29	24	22	23	10			
(10) *LM*	First perception (p)	2.73 ± .91	3.75 ±1.06	8.50 ±4.89	7.97 ±3.39	14.34 ±4.60	16.09 ±4.82	11.04 ±5.40	174	58
	Final appraisal (a)	2.00 ±0	—	5.00 ±2.33	5.60 ±5.12	9.36 ±4.97	6.50 ±4.00	6.95 ±4.51	87	29
	Ratio (p/a)	1.37:1	—	1.70:1	3.39:1	1.53:1	2.48:1	1.59:1		
	Collisions								261	87
	before (p)	43	42	32	19	21	17			
	after (p)	5	8	12	26	15	21			

the starting points will account, as we believe, for our results. When *S*, for example, started from the 6-ft position, he could stop for his 'first perception' only at points less than 6 ft and greater than 0 ft. (The trials at which he collided with the wall - the 0-ft points - were omitted from the calculations of the averages.) His average had to fall within those limits. When he started from the 12-ft position he had greater freedom of movement, he could stop anywhere between 12 ft and 0 ft; and similarly with the other starting points. By the chance hypothesis, the averages of the trials from the different starting points would increase with the distance of the starting points. Because our results show that relationship, we are led to conclude that our *S*s were guessing when they reported their 'first perceptions,' and that they neither possess the 'obstacle sense' nor the capacity to learn it.

'Final Appraisals': The general averages of our *S*s' attempts to approach the wall "as closely as possible without touching it," are large, varying from 3.00 ± 2.20 ft for *MS* to 8.21 ± 4.61 ft for *EH* (see Table II). These averages again greatly exceed those obtained from *S*s who demonstrated that they possessed the 'obstacle sense.' The averages, obtained in the earlier study under identical conditions, varied from 0.52 ± 0.04 ft to 0.56 ± 0.11 ft (see Supa, Cotzin, and Dallenback, pp. 11-13). The present results might mean, since the ability to perceive the wall varies inversely with the distance of the 'final appraisals,' that our

*S*s possessed the ability but in a low degree - just the opposite to the conclusion indicated by the gross averages of the 'first perceptions.' Even the conclusion, that they possessed it in a low degree, does not, however, seem to be warranted as the standard deviations are extremely high, varying from 53 to 73 percent of the averages.

The fractionation of the data and the separate computation of the averages for every starting point reveals, as with the 'first perceptions,' that the 'final appraisals' increase with the distance at which our *S*s started walking toward the wall; there is one exception, *HL* at the 30-ft starting point. For example, *DB*'s 'final appraisals' average 1.13 at 6 ft; 3.54 at 12 ft; 4.37 at 18 ft; 4.41 at 24 ft; 4.73 at 30 ft; and 5.71 at 36 ft. These results stand in striking opposition to those obtained under identical conditions in the earlier study in which the 'final appraisals' averaged approximately the same for all the starting points (see Supa, Cotzin, and Dallenbach, pp. 11-13). The present results indicate that distance,[8] and not the perception of the wall is the factor determining our *S*'s 'final appraisals.' Since the greater distances would by chance yield larger 'final appraisals,' the chance hypothesis seems to be the most reasonable explanation of our results. We are led, therefore, to reaffirm the conclusion expressed above that our *S*s neither possess the ability nor are capable of learning it.

Ratios of Performance: The ratios of performance (p/a) computed from the general averages vary from 1.50:1 for *EH* to 3.16:1 for *HL*, with 4 *S*s having ratios of less than 2:1 and only 1 *S* having a ratio of greater than 3:1. In comparison with the results of the earlier study, these ratios indicate that our *S*s, though about equal to the blindfolded, sighted *S*s, are greatly inferior to the blind *S*s (whose ratios were 35:1 and 12:1) with whom they should be compared. After a life time of getting about without vision and 300 trials spread through six experimental hours, our *S*s could do no better than blindfolded, sighted *S*s after 40 trials in a single experimental hour. Mediocrity of performance is all that the ratios reveal regarding our *S*s.

Collisions: Collisions with the wall were frequent, occuring in 79 (26 percent) of the trials for *DB*, the smallest number, and in 261 (86 percent) for *LM*, the largest number. Eight *S*s collided with the wall in more than 33 percent of the trials and 4 of them in more than 50 percent. Although most of the collisions occurred after the report of the 'first perception' while *S* was attempting to make his 'final appraisal,' every *S* collided with the wall in a few trials before he had reported his 'first perception.' For example: *DB* collided with the wall in 7 trials before reporting his 'first perception' and in 72 trials after reporting it; *GG*, in 44 trials before and 95 trials after; *JG*, in 8 trials before and 148 trials after, and so on. The results with 2 *S*s, however, reversed this relationship. *EH* and *LM* collided with the wall more

frequently before the 'first perception' (102 and 174 times respectively) than after it (68 and 87 times respectively).

Collisions before the 'first perception' are difficult to explain unless it be assumed that the *S*s making them lack the 'obstacle sense.' None of that type occurred in the normal series of the earlier study except when sighted *S*s were used before they had acquired the ability (see Supa, Cotzin, and Dallenbch, pp. 10-11). An *S* possessing the''sense' might by chance strike an obstacle when he was edging up to it to improve his 'final appraisal' but he would never collide with an obstacle as large and with as good a reflecting surface as the end wall of the experimental room without first perceiving it. If he did, serious doubt could be cast upon his possession of the 'obstacle sense.'

When the collisions are distributed according to starting point, the largest number is found to occur among the trials from the 6-ft point and the smallest number from the 36-ft point, with a gradual and regular decrease from the intermediate starting points. For example, out of 50 trials at every starting point, from shortest to longest, *GG* collided with the wall 45, 37, 28, 14, 10, and 5 times. If it be assumed that our *S*s possess the 'obstacle sense,' these results could only mean that the 'sense' is effective inversely with the starting distance - that is, it functions best when the *S*s start far away from the obstacle and poorest or not at all when they start close to it. A ridiculous conclusion, but one to which we are forced if we posit that our *S*s have the ability to perceive obstacles.

If, on the other hand, we assume that our *S*s lack the ability and are guessing, then the results become reasonable. By chance alone the *S*s would collide more frequently with the wall at the shorter starting distances and less frequently at the longer; and by chance alone the frequency of collision would vary inversely with distance. These results, therefore, confirm our chance hypothesis, and lead us again to reaffirm the conclusion that our *S*s possess neither the 'obstacle sense' nor the capacity to learn it.

The data presented in Table II are the composite of all the experimental hours; hence it may be argued that the *S*s learned to perceive obstacles during the course of the experiment, but that their learning was obscured by the inclusion of the later trials with the earlier ones. To test this speculation, we recorded the number of collisions made by the *S*s during every experimental hour, in each of which 50 trials were conducted. These data, given in Table III, show that none of the *S*s learned to perceive the wall to the extent that they entirely avoided collisions. Every one of them collided with the wall during the last 50 trials, the number of collisions varying from the

TABLE III

DISTRIBUTION OF THE COLLISIONS DURING THE SUCCESSIVE EXPERIMENTAL HOURS

S	Groups of 50 trials						Total
	1	2	3	4	5	6	
(1) *DB*	18	16	15	12	10	8	79
(2) *FB*	0	0	—	—	—	—	0
(3) *GG*	26	27	31	16	20	19	139
(4) *JG*	30	33	33	22	16	22	156
(5) *EH*	40	30	29	24	22	25	170
(6) *HL*	37	27	18	26	28	21	157
(7) *LM*	39	45	49	45	39	44	261
(8) *CR*	15	23	34	25	15	14	126
(9) *DR*	30	21	21	22	22	27	143
(10) *MS*	17	20	18	16	24	15	110

smallest, 8 for *DB*, to the largest, 44 for *LM*.

One *S* (*DB*) shows a progressive improvement during the experiment as his collisions numbered 18, 16, 15, 12, 10, and 8 during the successive series. Four others, *GG*, *JG*, *EH*, and *HL*, collided with the wall less frequently during the later than during the earlier series. The remaining *S*s (*LM*, *CR*, *DR*, and *MS*) show no improvement, at least not in reduction of collisions, as they ran into the wall about equally often in all of the series.

Must we conclude from these results that 5 of our *S*s gave some evidence of learning and that 4 did not? Before we come to any conclusion, we must know when the collisions of the different series occurred - that is, whether before or after the 'first perception.' If pre-'first-perception' collisions are more numerous during the early trials and post-'first-perception' collisions are more numerous during the later trials, then we may conclude, irrespective of the number or distribution of the unclassified collisions shown in Table III, that our *S*s learned something. Contrariwise, if the pre- and post-'first-perception' collisions are haphazardly distributed among the various series then we must conclude, irrespective of the reduction in the number of collisions in the later series, that our *S*s made no progress.

When the collisions were classified according to the time of their occurrence, we found for all the *S*s that the pre-'first-perception' collisions occurred more frequently during the early series and that they declined in number more or less regularly as the experiment progressed. They are clustered among the first three series for *DB* and *JG*, who made only 7 and 8 of them, respectively, and they are made in the last series by only 3 *S*s (*GG*, *EH*, and *LM*).

Do these results mean that all of our *S*s showed evidence of learning or that only 6 of them did? While we are willing to admit that the reduction in the number and distribution of the classified collisions indicate that the *S*s learned something, and will grant that that 'something' was to avoid collisions, we do not believe, in view of the results presented above, that any of them had acquired the 'obstacle sense.'

To learn to avoid collisions with the wall does not necessitate learning to perceive the wall. An *S* could avoid colliding with the wall if he learned to know how far away from it he was when he was brought to the different starting points, or if he learned to know from the feel of his feet the irregularities of the floor and their distances from the wall. These cues and many others, which only a handicapped man can appreciate, may serve in lieu of the 'obstacle sense' to avoid colliding with the wall and the punishment that that entails. If the *S*s used such cues as these, and as we shall presently see they reported that they did, results such as ours would follow.

At first, when the *S*s were unfamiliar with the experimental room, its distances and the irregularities of its floor, the collisions would be numerous and more pre-'first-perception' collisions would occur than at any other period. As the *S*s became better acquainted with the room, as they learned to know its dimensions and the irregularities of its floor, the collisions would decrease in number and fewer pre-'first-perception' collisions would occur. The reduction in the number of pre-'first-perception' collisions would mean that relatively more post-'first perception' collisions would occur, since the avoidance of the former would increase the probability of the latter occurring.

S'*s Comments and Behavior*

The *S*s were frequently questioned, both during and after the completion of the experiment, regarding the basis of their reports, and their behavior, during and before and after the trials as they went about the laboratory, was carefully observed. In answer to the questions, most of them replied "do not know," "am guessing," "just chance," "luck," but a few of them gave answers that shed light upon the basis of their own reports and also, because of similiarities of behavior, upon the basis of the reports of all the others. Brief accounts of their behavior and summaries of their answers to our questions are given below.

DB

Before starting to walk explored for bounding edges of carpet runners; was cautious; took unusually long strides; hit wall with feet, frequently in midstep, which saved body from blow of collision. Pace steady

and fairly rapid; did not slow up when nearing wall. Only answer to questions regarding cues was, "I walk well." In report at conclusion of trials, he wrote: "I walk the track between the carpet runners and I do well because I understand what is wanted and know the track," - that is, he knows the floor.

GG

Tried hard to acquire ability; showed great disappointment when he hit wall and great pleasure when 'final appraisals' were within a few feet of it - which they seldom were. "I don't know" was his answer to questions regarding cues.

JG

Walked with steady gait; stopped suddenly when signaling perception of wall. Counted steps on fingers until instructed to discontinue practice. May have counted them mentally thereafter. To questions regarding cues, replied "don't know."

EH

Walked slowly and at a uniform rate, did not vary pace at any point in path; collided with the wall in every trial at 6-ft and 12-ft starting points and in 42 of 50 trials at the 18-ft distance. Though cautioned against counting footsteps - and probably did not - seemed to walk a constant distance in all trials. Rapidly became familiar with experimental hall and parts of laboratory used by *S*s; moved about freely within those areas but "did not know" how she did it.

HL

No matter from what point started took 3 to 4 paces, stopped, and raised his right arm signaling 'first perception.' Walked at moderate rate down path without change of pace. Tried hard, greatly disappointed when collisions occurred and greatly pleased when 'final appraisals' were within 3 ft of the wall. To go from one part of the laboratory to another, he, more than any of the other *S*s, followed contour of walls and apparatus cases, positions of which he soon learned to know, with hands. His answer to question regarding cues was, "I possess good sense."

LM

Walked slowly with even gait; stopped suddenly when signaling a perception; did not slow down near wall. His successes, 39 out of 300 trials, were chance, "just luck" as

he reported. At conclusion of trials wrote, "Now I know 'facial vision' is no help to me. I do not know where the wall is when I walk. Guessed during the walks; successes are luck."

CR

Walked very slowly, paused frequently and stood still for short intervals during progress toward wall. The experimental hours had to be extended to obtain 50 trials. Though he moved about freely in everyday life - he traveled from Boston to Ithaca and back alone, as it will be recalled - he stated both in his letters and when he came to the experiments that he did not believe he possessed "the mysterious obstacle sense of the blind." As he could talk, he frequently commented, after a trial, upon his performance. For example, after a collision: "See, I haven't facial vision," "I haven't the obstacle sense," "I haven't got what it takes"; and after a close 'final appraisal': "That was just a guess," "I knew the wall was close because of a clue on the floor, an unevenness, and when I strike it, as I don't always do, I know it is time to stop."

At the conclusion of Experiment 1, *CR* typed the following report:

"I knew from the beginning that I could not perceive the wall, and that if I did it would be merely by accident. Consequently I at first guessed. After a while I became acquainted with the floor. Walking me around did not disorient me - not in the least. The floor told me where I was all the time; that is why I was able to do better as time went on. I could tell about where I was by the slopes and unevennesses of the floor and had I continued with the trials it would not have been long before I would have known the floor so well that I would not have run into the wall.

"At every trial, I knew approximately how far I was from the wall at the start. Even the experimenter's conversation [by the manual alphabet] while being conducted about the hall did not affect my appreciation of the approximate distance from the wall. I had no perception of the wall whatsoever; I did not crash into it oftener because I knew approximately how far it was away when I started walking toward it, and when I got close to it I could tell that I was coming near by the slight rise in and greater rigidity of the floor."

DR

Walked quickly and with long steps; hit the wall with great force, particularly in the pre-'first-perception' collisions. After trials in which 'final appraisals' were close, he wrote, in response to our praise, "just luck."

MS

Walked very slowly, pausing frequently for a few seconds. Wore hearing aid during all trials. Held head cocked to one side and projecting forward while walking toward wall. At suggestion of *FB*, slapped cheeks during every trial to 'sensitize' them to reflections from wall. Strove to 'listen' and to 'feel' because of earlier information regarding the 'obstacle sense.' Gave no explanation of her performances, but suggested that she was "probably guessing." Reported, at conclusion of last series, "I was not disoriented by being led about room; knew all the time about where I was."

Summary

Though the conditions in Experiment 1 were made as favorable as possible for the demonstration or learning of the 'obstacle sense,' none of these 9 deaf-blind *S*s, who were selected upon the basis of their ability to get about alone, was found to possess the ability and none of them was able, as we believe, to learn it. Though they did not run into the wall on every trial, their successes are best explaned by chance.

1. The average distances of their 'first perceptions' varied directly with the distance of the starting points - a result which stands in striking contrast to the finding in the earlier study where averages were obtained from *S*s possessing the ability that were approximately the same for all the starting points.

2. The standard deviations of the averages of our *S*s' 'first perceptions' followed a similar trend, again in opposition to the results of the earlier study.

3. The average distances of our *S*s' 'final appraisals' were measured in feet whereas those of the *S*s possessing the ability were measured in inches.

4. The average distances of our *S*s' 'final appraisals' varied directly with the distance of the starting points, in opposition to the results of the earlier study.

5. The variations of the averages of our *S*s' 'final appraisals' followed the same trend, again in opposition to the results of

earlier study.

6. The collisions varied in number with the distance of the starting points. In the earlier study the collisions bore no relation to the starting distances. They were not only few in number but were made when the *S*s were aware of the wall and were edging up on it to improve their positions. The *S*s in the present study ran into the wall on numerous trials and without knowing that they were near it.

7. All the *S*s reported at various times that they were guessing, and some of them reported that they knew about how far they were from the wall when placed at the starting points and also that they could judge the nearness of the wall by the "topography" of the floor.

Results of *FB*

Objective

FB's results, the composite of 100 trials made during the summers of 1941 and 1942 under the same conditions and method of procedure as Experiment 1 of this study, are also given in Tables II and III. (Dr. Milton Cotzin served as *E* during both of these series.) They differ markedly from the results of the other deaf-blind *S*s in this study. In the first place, *FB* did not collide with the wall during any of the trials. In the second place, he was unable to differentiate between 'first perception' and 'final appraisal,' although repeated efforts were made to teach him to do so. His 'first perception' was his 'final appraisal.' He did not detect the presence of the wall until he had approached it as closely as he thought possible without touching it. In the third place, his reports were not affected by the starting distance. They averaged approximately the same for all the starting points.

As Table II shows, his judgments for the 100 trials averaged 1.05 ± 0.14 ft. For the different starting distances, the averages vary from 1.03 ± 0.23 ft (6-ft starting point) to 1.09 ± 0.24 ft (30-ft starting point). From these results alone we must conclude that the presence of the wall was the determining factor in his reports. This does not mean, however, that his judgments were based on pressure cues. Quite on the contrary, from his comments and behavior there is evidence that they were not.

FB*'s Comments and Behavior*

FB was firmly convinced that he possessed the 'obstacle sense' and that sensations from his cheeks were the basis of his judgments. He could not, however, describe these sensations. All that he could say about the experience was "I just feel the wall in my cheeks when I come close to it." His gross behavior in

part bore him out for he frequently slapped his cheeks ("to sensitize them" as he expressed it) as he walked toward the wall.

If the "sensations from his cheeks" found the wall for him when he was about a foot from it, some other cues were serving him well when he was at other positions in the hall because he could not be 'lost' in it. He retained his orientation and knew approximately where he was with respect to the wall no matter how circuitous the route taken in walking him to a starting position. Talking to him and engaging him in conversation to distract his attention the while did not confuse him in the slightest. If he could retain his orientation within the hall without recourse to "facial vision," it may well be that the location of the wall could also be explained without it.

In regard to his ability to retain his orientation in the hall, *FB* stated that he accomplished it by means of cues received through his feet from the floor. The floor was as a relief map, and he knew at all times where he was by reference to its irregularities: here was a rise, there a depression, and the like, and he was, in particular, made aware of nearing the wall by the floor's increased rigidity. May not, therefore, his knowledge of the 'topography' of the floor of the experimental hall be the basis of his reports of the wall? Experiment 1 was not designed to answer that question.

In *FB*'s case there are, however, still other alternatives. He may also have used audition or vision to detect the wall. He wore his hearing aid during the trials of this experiment and he may in consequence have located the wall by means of auditory cues. That is possible but highly improbable, as we believe, because he was totally deaf in his right ear and could not hear with his left ear (see Figures 1 and 2) above 2896 cycles nor below that frequency at intensifications of less than 60 dB - a degree of hearing that was found in the earlier study to be totally inadequate to obstacle perception (see Supa, Cotzin, and Dallenbach, pp. 35-39).

Vision is much more probable. Though his left eye was enucleated, he had, it will be recalled, light and color perception in his right eye and could detect hand movements against a bright background with it. Despite the fact that he wore a blindfold during the trials, as did all the *S*s, he may have seen under it sufficiently well to have differentiated between the presence and absence of a large object, such as the wall. He did not wear the blindfold tightly nor snugly over his eyes, as did the other *S*s, and he would not permit the placing of an adequate pad of cotton wool over his eye under the blindfold nor the closing of his eye with adhesive tape. These precautions to insure that he did not see distracted and confused him and obscured the pressures in his cheeks.[9] They were consequently dispensed with in his case and he was permitted to adjust the blindfold to suit himself. He was instructed, however, to keep his eyes tightly closed during all

the trials, which would have eliminated vision if he had done so. He reported, in answer to frequent inquiries, that he kept them closed but it is probable that unknowingly he did not. There was, in the first place, the possibility of his seeing; a sighted *S* could easily have seen from beneath the blindfold as *FB* adjusted it upon himself. Again, his behavior, in particular the position in which he held his head as he walked toward the wall, was that of a person peering from under the blindfold over the bridge of his nose. His result - inability to differentiate between 'first perception' and 'final appraisal' and the constancy of report at the 1-ft mark - were, furthermore, those that would be expected from visual equipment such as his.

Conclusions

FB's results, if accepted at their face value, confirm the pressure theory. There is, however, good reason in his case to suspend judgment. He detected the wall, that much is certain, but he may have located it by his knowledge of the distance of the starting point from the wall, by cues derived from the floor, by audition, or even by vision. All that his results show is the need for further experiment in his case.

Experiment 2

Depsite the results of Experiment 1, or our interpretation of them, it may be that *FB* did possess the 'obstacle sense,' and the other *S*s did learn something of it. Though their data were fractionated that the failures in the earlier trials would not obscure the later successes, learning may have been so slight and slow that obscuring did occur. A retest of the *S*s would alone suffice to decide that point.

If a retest showed improvement, however, we should still have to determine whether it was learning to apprehend the obstacle or to attach meaning to secondary cues associated with the obstacle. As long as *S* approached a fixed object (for example, a wall), the unevenness of the floor might serve him in locating it. He might know from his familiarity with the floor approximately how far he was from the wall when placed at the starting point. Knowing that, he might estimate the distance through which he walked and stop short of the wall without apprehending it. Again, he might know from certain changes in the floor (for example, its increased rigidity), that he was nearing the wall and stop because of those 'signs' without sensing the wall per se. Experiment 2 was undertaken to resolve these problems.

In Experiment 2, a repetition of Experiment 3 of the earlier study from this Laboratory (see Supa, Cotzin, and Dallenbach, pp. 19-23), we sought to eliminate the secondary cues that our *S*s received from the floor, and to retest our *S*s to determine whether they had made any progress in learning the 'obstacle sense.'

Procedure

In order to eliminate the secondary cues derived from the floor, since we could not remove its unevenness, we used a movable obstacle. This obstacle, a 1/4 in. sheet of masonite, 4 ft wide, 4 ft 10 in. high, mounted on a stand with the lower edge 2 ft above the floor, was placed at variable positions in the center of the hall, and *S* approached it from various starting points. He walked with shoes on over a bare hardwood floor and down a 30-in. path between two carpet runners. His starting positions were 0, 3, 6, 9, and 12 ft from the end wall of the hall that had been used in Experiment 1 as the obstacle. The screen was placed at distances of 6, 12, 18, 24, and 30 ft from the specific starting point used. The starting points and the obstacle distances were both varied in planned haphazard order which guaranteed that they were used equally often and not in fixed sequences.

Vexierversuche - that is, blank or check trials in which the screen was placed not in *S*'s path but against one of the side walls of the hall - were introduced to determine the degree that the *S*s were guessing in their reports. These trials were interspersed among the 'true' trials in planned haphazard order which insured that they would come as frequently after one starting point and obstacle distance as after every other. None of the *S*s knew that these 'blank' trials were given.

Between the successive trials, *S* was conducted to an anteroom where he remained while *E* placed the screen in its next position, or removed it, as the experimental plan demanded.

S was permitted to run into the screen, as in Experiment 1, and when he had made a 'final appraisal' he was led to the screen to show him how far he was away from it. No other 'punishment' or 'reward' was given him. In the case of the 'blank' trials, *S* was returned to the anteroom without comment immediately after reporting a 'final appraisal,' or after he had walked the length (42 ft) of the carpet runner, without signaling a 'first perception.'

All the *S*s served in this experiment. They were blindfolded as before and two of them (*FB* and *MS*) wore their hearing aids.

The instructions were the same as in Experiment 1 except for an added paragraph informing *S* that he would be placed in an anteroom between successive trials. Every *S* was given 150 trials: 25 at every one of the 5 separations between starting point and screen, and 25 'blank' trials.

Results

Objective

The results of this experiment are very similar to those of Exper-

iment 1. *FB* perceived the wall at every trial and, as before, he was unable to differentiate between 'first perception' and 'final appraisal.' His reports averaged approximately the same in the two experiments (a little over 1 ft) and the averages and deviations were again practically the same for all the obstacle-distances, varying, as shown in Table IV, from 1.20 ± 0.29 ft at the 6-ft distance to 1.28 ± 0.30 ft at the 30-ft distance. His general averages in the two experiments were 1.05 ± 0.14 ft and 1.24 ± 0.31 ft, a difference of 0.19 ft in favor of Experiment 2. This difference, however, is not significant as it is less than our unit of measurement, 0.5 ft. Our *S*s' performances, as it will be recalled, were measured only to the nearest 6 in.

The fact that his performances were practically the same in the two experiments indicates that his knowledge of the starting distance and nearness of the wall, which he claimed to have gained in Experiment 1 from the unevennesses of the floor, was of little or no value to him. He did as well without that knowledge in Experiment 2 as with it in Experiment 1.

His results should not, however, have been the same in the two experiments. The significance of the cues from the floor was eliminated in Experiment 2, and the masonite screen used as the obstacle presented a much smaller reflecting area and a much poorer reflecting surface than the hard plastered, gloss painted, stone end wall of the hall. If *FB*'s performance was dependent on secondary cues derived from the floor, or on primary cues derived from the reflection of 'air-' or soundwaves, either felt or heard, his results should have been poorer under the conditions of Experiment 2 than under the more favorable conditions of Experiment 1. The blind *S*s in the earlier study, under exactly the same conditions, gave considerably poorer results when the screen was substituted for the wall (compare Tables I and III in Supa, Cotzin, and Dallenbach, pp. 11 and 21). That *FB* did not, places his results in suspect. The possibility of vision was the only condition that was unchanged in his case in the two experiments, as he was again, with the admonition that he was to keep his eye closed, permitted to adjust the blindfold to suit himself. Could it be that he unconsciously opened his eye? Did he see a vague shadow from beneath the blindfold when about a foot from the obstacle? Were his reports based on vision? Further experiments with him were planned to answer these questions.

As a retest to determine whether the other *S*s had made any progress in learning the 'obstacle sense' in the 300 trials of Experiment 1, Experiment 2 was a failure. It showed (see Table IV) merely that they still lacked it. The general averages of their 'first perceptions' are smaller than in Experiment 1 - that is, they did not report the obstacle from as great a distance; and the general averages of their 'final appraisals' are larger - that is, they did not approach the obstacle as closely. The de-

TABLE IV

RESULTS OF EXPERIMENT 2

Average Distance and Variation (in Ft) of the 'First Perceptions' and 'Final Appraisals,' Performance Ratios, and Number of Collisions for Every Obstacle-Distance.

S	Report	Obstacle-distance (in ft.) 6	12	18	24	30	General average	Collisions No.	%
(1) DB	First perception (p)	2.44 ± .84	6.11 ± 4.15	8.52 ± 4.34	13.56 ± 3.98	18.96 ± 5.08	10.88 ± 5.62	22	18
	Final appraisal (a)	1.00 ± .67	2.55 ± 1.49	7.38 ± 3.23	8.56 ± 4.82	10.79 ± 7.04	7.82 ± 5.47	36	28
	Ratio (p/a)	2.44:1	2.40:1	1.15:1	1.58:1	1.76:1	1.39:1		
	Collisions							58	46
	before (p)	16	6	0	0	0			
	after (p)	6	8	13	8	1			
(2) FB	First perception (p)	1.20 ± .29	1.22 ± .31	1.24 ± .31	1.24 ± .33	1.28 ± .30	1.24 ± .31	0	0
	Collisions	0	0	0	0	0	0		
(3) GG	First perception (p)	0	3.65 ± .92	8.64 ± 2.28	13.92 ± 3.44	16.92 ± 4.25	11.40 ± 5.12	38	30
	Final appraisal (a)	0	0	2.50 ± .50	5.42 ± 2.71	7.50 ± 5.21	5.98 ± 3.88	56	45
	Ratio (p/a)	—	—	3.46:1	2.57:1	2.26:1	1.91:1		
	Collisions							94	75
	before (p)	25	8	3	1	1			
	after (p)	0	17	18	11	10			
(4) JG	First perception (p)	2.96 ± 1.28	7.32 ± 1.41	11.36 ± 3.25	16.12 ± 2.68	22.84 ± 4.20	13.25 ± 6.20	15	12
	Final appraisal (a)	1.00 ± 0	3.94 ± 2.34	6.38 ± 3.74	9.63 ± 2.54	12.67 ± 6.22	7.44 ± 4.67	68	54
	Ratio (p/a)	2.96:1	1.86:1	1.78:1	1.67:1	1.80:1	1.78:1		
	Collisions							83	66
	before (p)	12	3	0	0	0			
	after (p)	10	13	12	17	16			
(5) EH	First perception (p)	0	1.94 ± 1.06	5.92 ± 2.32	9.60 ± 2.64	15.24 ± 3.27	9.45 ± 4.57	42	34
	Final appraisal (a)	0	0	2.36 ± 1.03	3.65 ± 1.75	8.25 ± 3.40	5.40 ± 3.13	28	22
	Ratio (p/a)	—	—	2.51:1	2.63:1	1.85:1	1.75:1		
	Collisions							70	56
	before (p)	25	17	0	0	0			
	after (p)	0	8	14	5	1			
(6) HL	First perception (p)	2.57 ± .96	7.60 ± 1.49	12.20 ± 2.13	18.92 ± 2.75	24.60 ± 1.65	13.53 ± 3.78	4	3
	Final appraisal (a)	0	5.67 ± 1.78	7.00 ± 1.33	7.00 ± 2.00	5.85 ± 4.25	6.24 ± 3.19	96	77
	Ratio (p/a)	—	1.34:1	1.74:1	2.70:1	4.21:1	2.17:1		
	Collisions							100	80
	before (p)	4	0	0	0	0			
	after (p)	21	22	22	19	12			
(7) LM	First perception (p)	0	1.67 ± .44	3.00 ± 0	10.00 ± 4.00	15.50 ± 6.83	9.13 ± 7.08	112	89
	Final appraisal (a)	0	0	0	0	0	0	14	11
	Ratio (p/a)	—	—	—	—	—	—		
	Collisions							125	101
	before (p)	25	23	22	22	19			
	after (p)	0	2	3	3	6			
(8) CR	First perception (p)	0	5.17 ± 1.11	7.92 ± 1.80	10.07 ± 3.34	14.31 ± 3.98	10.29 ± 4.09	76	61
	Final appraisal (a)	0	3.25 ± .88	5.80 ± 1.64	7.64 ± 1.82	11.47 ± 4.43	8.18 ± 3.57	9	7
	Ratio (p/a)	—	1.59:1	1.37:1	1.32:1	1.25:1	1.26:1		
	Collisions							85	68
	before (p)	25	19	12	11	9			
	after (p)	0	2	3	3	1			

TABLE IV - (continued)

S	Report	Obstacle-distance (in ft.) 6	12	18	24	30	General average	Collisions No.	%
(9) *DR*	First perception (p)	0	5.27 ±2.25	7.95 ±3.04	9.00 ±3.71	15.92 ±5.34	10.31 ±4.93	47	38
	Final appraisal (a)	0	0	7.20 ±2.56	5.00 ±2.50	9.60 ±4.12	8.00 ±3.68	59	47
	Ratio (p/a)	—	—	1.10:1	1.80:1	1.66:1	1.29:1		
	Collisions							106	85
	before (p)	25	14	3	4	1			
	after (p)	0	11	17	17	14			
(10) *MS*	First perception (p)	2.71 ± .42	5.00 ±1.87	7.32 ±2.71	10.04 ±3.21	15.96 ±4.63	9.55 ±4.76	33	26
	Final appraisal (a)	0	3.17 ± .89	3.04 ±1.51	4.04 ±2.12	6.00 ±3.79	4.40 ±2.41	40	32
	Ratio (p/a)	—	1.58:1	2.41:1	2.49:1	2.66:1	2.17:1		
	Collisions								
	before (p)	18	10	3	1	1			
	after (p)	7	9	9	10	5			

crease in their performances is perhaps more clearly shown in the ratios of their 'first perceptions' to their 'final appraisals' (p/a). Seven of the *S*s had smaller ratios in Experiment 2 than in Experiment 1, and two (*EH* and *MS*) had ratios that were about the same.

The percentage of trials in which collisions occurred was greater in Experiment 2 than Experiment 1 for all the *S*s except *EH* (see Table IV). The increase varied from 13 percent for *LM* (from 87 percent to 100 percent) to 37 percent for *DR* (from 48 percent to 85 percent). *EH* made approximately the same percentage, 56 percent and 57 percent in the two experiments.

The fact that our *S*s' performances were poorer in every respect in this experiment than in the preceding one, suggests that in Experiment 1 they probably used the information received from the floor through their feet regarding the starting point position of the wall. The floor's 'topography' would have significance in relation to a fixed obstacle, in particular the wall, but it would have no meaning in relation to a movable obstacle.

When the trials were divided according to the distance between the starting point and obstacle, the averages and deviations of the 'first perceptions' and 'final appraisals' were found to

vary directly and the number of collisions to vary inversely with obstacle distance (see Table IV). That obstacle distance, not the obstacle, was the decisive factor in our *S*s' reports, leads us to reaffirm the conclusion tentatively drawn in Experiment 1 - namely, that our *S*s were guessing in making their reports and that their successes, such as they were, were due to chance.

In order to determine whether there was any improvement in our *S*s' performances during Experiment 2, the number of collisions for every successive series of 25 trials was tabulated separately for every *S*. The results of this tabulation show no regular nor

TABLE V

DISTRIBUTION OF THE COLLISIONS IN THE SUCCESSIVE SERIES OF 25 TRIALS

S	Series of 25 Trials 1	2	3	4	5	Total	χ^2	P
(1) *DB*	16	11	11	11	9	58	2.34	80–90
(2) *FB*	0	0	0	0	0	0	—	—
(3) *GG*	16	21	17	20	20	94	.74	90–95
(4) *JG*	18	15	16	17	17	83	.31	98–99
(5) *EH*	16	13	16	11	14	70	1.29	80–90
(6) *HL*	23	20	20	19	18	100	.70	95–98
(7) *LM*	25	25	25	25	25	125	.00	99–100
(8) *CR*	14	16	17	17	21	85	1.53	80–90
(9) *DR*	22	25	23	18	18	106	1.83	70–80
(10) *MS*	19	13	20	8	13	73	6.66	10–20

consistent trend (see Table V). The number of collisions diminishes slightly in the later series for some of the *S*s and increases slightly for others. For example: *DB* collided with the wall in the successive series 16, 11, 11, 11, and 9 times; *MS*, 19, 13, 20, 8, and 13 times; *GG*, 16, 21, 17, 20, and 20 times; *CR*, 14, 16, 17, 17, and 21 times, and so on. When we set up the hypothesis that the differences among the series were due to chance and tested it by the method of chi-square; we found that it was tenable. In not a single instance, as Table V shows, was a significant value of χ^2 obtained - the lowest, that for *MS*, being between the 10 to 20 percent level.

Twenty-five 'blank' trials were conducted. During these trials, 'first perceptions' and 'final appraisals' were reported by every one of our *S*s except *FB*. The number of these *Vexierfehler*, or 'false' reports, made by every *S* is given in Table VI. *FB* made

TABLE VI

RESULTS OF 'BLANK' TRIALS

Number of 'False' Reports, Distribution of the Distances Walked in 6-Ft Intervals before Making Them, the Theoretical and Observed Number of Collisions, the Difference Between Them and Critical Ratio of the Difference.

S	Report	No. 'false' reports	Distances walked (in ft.)							Collisions		Diff.	C.R.
			1–6	7–12	13–18	19–24	25–30	31–36	37–42	theo.	obs.		
(1) *DB*	First perception (p)	25	6	6	7	6	0	0	0	72	58	14	1.04
	Final appraisal (a)	25	0	6	4	7	3	5	0				
(2) *FB*	First perception (p)	0	—	—	—	—	—	—	—	125	0	125	0
(3) *GG*	First perception (p)	25	1	15	7	2	0	0	0	96	94	2	.18
	Final appraisal (a)	25	0	1	1	8	6	5	4				
(4) *JG*	First perception (p)	25	8	7	10	0	0	0	0	93	83	10	.82
	Final appraisal (a)	24	0	4	1	3	6	1	9				
(5) *EH*	First perception (p)	25	0	10	11	4	0	0	0	77	70	7	.42
	Final appraisal (a)	25	0	0	6	12	6	1	0				
(6) *HL*	First perception (p)	25	15	10	0	0	0	0	0	93	100	7	.60
	Final appraisal (a)	25	0	1	2	7	7	3	5				
(7) *LM*	First perception (p)	5	0	0	0	1	2	0	2	125	125	0	.00
	Final appraisal (a)	0	0	0	0	0	0	0	0				
(8) CR	First perception (p)	11	2	1	1	4	3	0	0	107	85	22	2.07
	Final appraisal (a)	10	0	2	0	1	7	0	0				
(9) DR	First perception (p)	25	0	7	9	4	3	2	0	99	106	7	.70
	Final appraisal (a)	12	0	1	0	3	5	2	1				
(10) MS	First perception (p)	24	1	1	1	8	11	2	0	105	73	32	8.10
	Final appraisal (a)	13	0	0	3	3	5	1	1				

none; in every 'blank' trial he walked the length of the carpet runner without reporting. Of the other *S*s, *LM* made 5 false 'first perceptions'; *CR* made 11; *MS*, 24; and each of the remaining six *S*s, 25. False 'final appraisals' were slightly less numerous: *LM* made none; *CR* made 10; *MS*, 13; *JG*, 24; and each of the remaining five *S*s, 25.

Since the *S*s did not know when the 'blank' trials occurred, or even that they were to be given, their reports in these trials may be samples of their reports in the entire experiment. In *LM*'s case it appears from casual inspection that they are. In 25 'blank' trials, he reported 5 'first perceptions' and no 'final appraisals.' In 125 trials with the obstacle, he reported 15 'first perceptions' and no 'final appraisals.' Although the results of the 'blank' trials considered alone might suggest that *LM* possessed the ability to perceive obstacles in a high degree since he made no 'final appraisals' - that is, did not report the obstacle when it was not present - that is not, as we believe, the explanation. The reason that he did not report that obstacle in the 'blank' trials when it was not present was because he did not report it in the 'main' trials when it was present. Not to report was the pattern of his responses. He was behaving the same in the 'blank' as in the 'main' trials. His reports in both series were of a kind.

The homogeneity of *LM*'s data may be judged by inspection, but the data of the other *S*s are more complex and require statistical treatment to enable us to determine whether their reports in the two samples are homogeneous. To this end, we tabulated the distances in 6-ft intervals through which the *S*s walked in the 'blank' trials before giving their reports (see Table VI). For example: *DB* reports six 'first perceptions' after walking distances of 1 to 6 ft; six, 7 to 12 ft; seven, 13 to 18 ft; six, 19 to 24 ft; and none beyond that. He reported no 'final appraisals' after distances of 1 to 6 ft, but did report six after distances of 7 to 12 ft; four, 13 to 18 ft; seven, 19 to 24 ft; three, 25 to 30 ft; five, 31 to 36 ft; and none beyond that. With these distances as a pattern of *S*'s responses we calculated the number of times, in 25 trials at every obstacle distance used in the 'main' trials, that collisions would have resulted if the obstacle had been in his path at those set distances.

As Table VI shows, *DB* would have collided with the obstacle 72 times; *GG*, 96 times; *LM*, 125 times; *MS*, 105 times, and so on. These 'theoretical' values were then compared with the values obtained in the 'main' trials (the 'observed' values), and the differences and their critical ratios were calculated for every *S* to determine whether the two samples were homogeneous. If they were of a kind, the critical ratios would be small; if they were not, the ratios would be large.

Of the nine critical ratios computed, six range between 0.00 to 0.82; one is 1.04; one, 2.07; and one, 8.10. Only one of these ratios, 8.10 for *MS*, is large enough to be considered significant. All the others are so low that the two samples from which they are computed must be regarded as homogeneous. (*LM*'s ratio, whose data we judged to be homogeneous by inspection, was 0.00. His 'theoretical' and 'observed' collisions were each 125.) Conclusions drawn regarding one sample would, therefore, apply

with equal cogency to the other. Since we know that the reports of our *S*s in the 'blank' trials were determined by chance, we may now safely conclude that the reports of all the *S*s in the 'main' trials except those of *MS*, were also determined by chance.

In *MS*'s case, the difference between the number of 'theoretical' and 'observed' collisions is, as we have seen, statistically significant. This means that the patterns of her reports in the two samples are not the same. Since she wore a hearing aid during the trials, her ability to hear might be the differentiating factor. Further experiments in her case are needed to decided this point.

S'*s Comments and Behavior*

When requested, after the experiment, to explain the basis of the reports given during the trials, all of the *S*s, except *FB* and *MS*, replied that they were "guessing" - as the objective results revealed; and that their close 'final appraisals' (those of 1 to 2 ft) were "chance" or "luck."

FB was more certain than ever that he was using 'facial vision,' since his performance was not affected by the loss of the significance of the cues from the floor. He reported in explanation of his performances, "I locate the screen by pressures in my cheecks." *MS* hazarded no explanation. She reported, "I signal when I think the obstacle is there"; and, to questions set to discern why she thought it was "there," she said, "I do not know."

The behavior of the *S*s during this experiment was the same as in Experiment 1. *FB* and *MS* slapped their cheecks as before "to sensitize them to reflected waves"; and *FB* again walked with head held back and chin elevated as if he were looking out from beneath the blindfold.

Summary

Experiment 2 was undertaken to eliminate the secondary cues of the obstacle that the *S*s received from the floor through their feet, and to retest the *S*s to determine whether they had learned to perceive obstacles in the previous experiment. A small movable screen instead of the wall was used as the obstacle. It was placed at different points near the center of the hall, and *S* approached it from various starting points at one end of the hall. Between successive trials, while the screen was being placed at the desired position, *S* was in an anteroom. To ascertain the extent to which our *S*s were guessing in their reports, one 'blank' or 'check' trial, in which the obstacle was not present, was interspersed, without the *S*s' knowledge, in every series of five trials with the obstacle.

1. *FB* perceived the wall in every trial with the obstacle at average distances slightly greater than in the preceding experiment and he made no 'false' reports in the 'blank' trials. That he did as well or better under less favorable conditions - loss of cues from the floor and decrease in size and reflecting value of the obstacle - places his results in suspect. His behavior during the trials added to the misgiving. He may unknowingly have used vision to detect the obstacle; a possibility that our conditions in his case were not rigorous enough to prevent. The necessity of further experiments with him was indicated.

2. All of the other *S*s reported 'first perceptions' and 'final appraisals' and collided with the screen. Performance was, however, poorer on the whole than in the first experiment: (a) they did not report the obstacle from as great a distance; (b) they did not approach it as closely; (c) their performance ratios, p/a, were smaller; and (d) the number of their collisions was much larger.

3. The averages and deviations of their 'first perceptions' and 'final appraisals' varied directly with the distance between the obstacle and the starting point, and the number of collisions varied inversely with that distance. Obstacle distance, and not the obstacle, was again found to be the decisive factor in our *S*s' reports.

4. Our *S*s showed no improvement in avoiding collisions during the course of the experiment. Approximately the same number was made in the late as in the early trials. The differences among the five series of 25 trials each are slight and appear to be due to chance - a hypothesis that the statistical treatment of the data sustained.

5. *Vexierfehler*, both false 'first perceptions' and false 'final appraisals,' were reported in the 'blank' trials in varying numbers by all the *S*s. By inspection the 'blank' and 'main' trials of one *S* were judged to be homogeneous. The data of all the *S*s were, as a consequence, examined to see if they too were not homogeneous. The 'theoretical' number of collisions that would have resulted if an obstacle had been at the set positions in the 'blank' trials was correlated with the number of collisions observed in the 'main' trials. The differences between the 'theoretical' and 'observed' numbers were small and their critical ratios were insignificant in all cases except one - an *S* who used a hearing aid during the trials. For all the other *S*s, the conclusion is warranted that the two samples are homogeneous, which means that performance in the 'main' trials are as much matters of chance as in the 'blank' trials.

6. All the *S*s, except *FB* and *MS*, reported that they were guessing and their objective results bear them out.

Experiment 3

In the preceding experiments, *FB*'s and *MS*'s results were out of line with those of the other *S*s. *FB*'s were entirely so. He perceived the obstacle in every trial at distances that were relatively constant for all starting points and obstacle distances. *MS*'s results on the other hand, were only slightly out of line; they differed from those of the other *S*s in only one respect, her 'blank' and 'main' trials were not homogeneous. Something in addition to chance was determining her reports either in the 'main' or in the 'blank' trials.

Both *FB* and *MS* could hear to a slight degree which none of the other *S*s could do. Both wore hearing aids in everyday life and both were permitted to wear them during the course of the preceding experiments. It may very well be, therefore, that the differences between their results and those of the other *S*s were due to their ability to hear. Experiment 3, a repetition of Experiment 5 of the earlier study (see Supa, Cotzin, and Dallenbach, pp. 35-39), was conducted to determine whether this was the case.

Procedure

S was deprived of his hearing aid and, to insure that he did not use the little hearing that was left him, an MSA Ear-Defender (see footnote 10 in Supa, Cotzin, and Dallenbach, p. 52) was inserted into the external auditory meatuses of each of his ears. Over the defender and fitting snugly into the pinna, a plug composed of a mixture of beeswax and cotton wool was placed, and over this plug a beeswax-cotton shield, two layers of cotton batting, and wool-lined ear muffs; the whole being held tightly in place by the elastic bands of the blindfold. Under these conditions the *S*s were totally deaf.

The procedure and instructions were the same as in Experiment 2. The trials with *FB* were conducted during the summers of 1941 and 1942 (Dr. Milton Cotzin served as *E* during both of these series), those with *MS* immediately following Experiment 2. *FB* completed 10 trials at every one of the 5 obstacle distances each summer - 100 trials in all. *MS* completed 150 trials: 25 at every obstacle distance and 25 'blank' trials.

Results

FB's results are similar to those obtained from him in the proceding experiments. He perceived the obstacle at distances of about 1 ft in every trial. Audition does not, therefore, explain the difference between his results and those of the other *S*s. The consistency of his performances without audition, and in the preceding experiment without the cues from the floor, leaves us with these alternatives: he perceived the obstacle either by 'facial vision'

as he claimed (which the four *S*s in the earlier study were unable to do or to learn), or by vision, which was possible in his case since he possessed light and color perception in one eye and wore his blindfold loosely.

As we pointed out above, his performance in the experiments in which the movable masonite screen was used as the obstacle should not have been as good as that in which the wall was used. If 'facial vision' were the basis of his perception, he should have approached the screen more closely than the wall because the intensity of the waves reflected by the screen is weaker than those reflected by the wall. That he did not, cast serious doubt upon the first alternative. The second was investigated in Experiment 4.

MS's results are given in Table VII. The general averages and deviations of her 'first perceptions' and 'final appraisals,' ratio of performance (p/a), and number of collisions are of the same order as in Experiment 2.[10] When her trials, moreover, are divided according to the distance between starting point and obstacle, the averages and deviations of the 'first perceptions' and the 'final appraisals,' performance ratios, and number of collisions are again found, as in Experiment 2, to vary with obstacle distance. From the similarity of the results of the two experiments, it appears that *MS*'s performance was not affected by the loss of the little hearing that she possessed. However, that is not, as we believe, entirely the case, for the pattern of her performances is different in the 'blank' trials in two experiments.

Though she made practically the same number of collisions with and without hearing (73 and 72 respectively), their distribution among the various obstacle distances is very different in the two experiments. With hearing, the number decreases rather gradually as the obstacle distance increases (see Table IV); without hearing the number decreases precipitously (see Table VII). *MS*'s results in Experiment 3 indicate that she was no longer 'guessing' haphazardly but was following a general tendency to report after walking set distances. At least her results can readily be explained by the assumption that she walked about 10 ft before reporting a 'first perception' and about 10 ft more before reporting the 'final appraisal.' For example, by walking about 10 ft before reporting a 'first perception' she would collide with the obstacle in every trial at the 6-ft obstacle distance, in some at the 12-ft distance, and in none or very few beyond that distance - which is precisely what she did. She collided in 25 (100 percent) of the trials at the 6-ft distance, in 7 (28 percent) at the 12-ft distance, and in 3 (4 percent) beyond the 12-ft distance. By walking, after reporting a 'first perception,' about 10 ft more before reporting the 'final appraisal,' she would collide with the obstacle in every remaining trial at the 12-ft distance and most of them at the 18-ft distance - which is again what she did. She collided in the 18 remaining trials (100 percent, since collisions had occurred

before the 'first perception' in 7 of the 25 trials) at the 12-ft distance, in 16 of the remaining 24 trials (66 percent) at the 18-ft distance, and in only 3 (6 percent) at distances beyond that.

TABLE VII

THE RESULTS OF *MS* IN EXPERIMENT 3

Average Distance (in Ft) of *MS*'s 'First Perception' and 'Final Appraisal,' the Performance Ratios, and Number of Collisions for Every Obstacle Distance.

Report	Obstacle-distance (in ft.)					General average	Collisions	
	6	12	18	24	30		No.	%
First perception (p)	—	4.94	8.92	13.42	18.13	11.72	35	28
	—	±1.39	±2.85	±3.31	±4.67	±5.43		
Final appraisal (a)	—	—	3.75	6.92	8.38	7.02	37	30
	—	—	±2.25	±2.42	±2.74	±2.85		
Ratio (p/a)	—	—	2.38:1	2.01:1	2.16:1	1.67:1		
Collisions							72	58
before (p)	25	7	1	0	2			
after (p)	—	18	16	1	2			

The tendency to report after walking set distances is also observable in 'false' reports of this experiment. Table VIII shows the distances, in 6-ft intervals, which *MS* walked before giving her reports. Although the distribution is in units incommensurate with 10, we can see from insepction that her false 'first perceptions' cluster at distances of about 10 ft, and that most of her false 'final appraisals' are reported within the next 10 ft. To determine more accurately whether the 'blank' and 'main' trials are alike in kind, we computed, from the pattern of her performance in the 'blank' trials, the 'theoretical' number of collisions that would have resulted if 25 trials at each of the 5 obstacle distances had been given her and an obstacle had been in her path. The 'theoretical' number obtained was 71. The number of collisions observed in the 'main' trials was 72. The difference between the 'theoretical' and 'observed' number is so slight and its critical ratio is so small (0.07) that it must be regarded as insignificant. We may safely conclude, therefore, that the two samples are homogeneous and that *MS*'s reports in both are due to chance.

TABLE VIII

MS's 'FALSE' REPORTS IN EXPERIMENT 3

Number of *MS*'s 'False' Reports, Distribution of the Distances She Walked in 6-Ft Intervals before Making Them, the 'Theoretical' and 'Observed' Number of Collisions, the Difference between Them, and the Critical Ratio of that Difference.

Report	No. 'false' reports	Distance walked (in ft.)							Collisions		Diff.	C.R.
		1–6	7–12	13–18	19–24	25–30	31–36	37–42	theo.	obs.		
First perception (p)	24	1	14	8	1	0	0	0	71	72	1	0.07
Final appraisal (a)	23	0	3	7	8	5	0	0				

The 'theoretical' number of collisions resulting from the pattern of her reports in the 'blank' trials in Experiment 2 (105) is very different, however, from the 'theoretical' number in Experiment 3 (71). Because the difference (34) and its critical ratio (8.55) are large, we must conclude that the two series of 'blank' trials are heterogeneous and that something was influencing her reports in one series that was not influencing them in the other.

Hearing, as will be recalled, was the only difference between the conditions of the two experiments. If it is responsible for the heterogeneity of the results of the two series of 'blank' trials, it must also be responsible for the homogeneity of the results of the other series - the 'main' trials of Experiment 2 (73 'observed' collisions) and the 'blank' and 'main' trials of Experiment 3 (71 'theoretical' and 72 'observed' collisions, respectively). We believe it is. When *MS* was totally deaf she possessed no meaningful cues of the obstacle. Her reports of it were determined by chance, as the objective results reveal. When she had partial hearing and the obstacle was in her path the reflections of the soundwaves aroused vague, indefinite, auditory cues - not sufficient to aid her in avoiding the obstacle but sufficient to set her at ease, since they were normal to her everyday life - and her reports were again determined by chance. They were in consequence homogeneous with the reports given when totally deaf, as the objective results reveal. When, however, the obstacle was not in her path, as in the 'blank' trials of Experiment 2, the auditory experiences normal to her were either replaced by a new set of auditory cues from reflections from the end wall of the hall or were totally lacking. In either case, the want of the habitual interspersed among a series

in which the habitual prevailed might well be expected to yield a pattern of report different from that in the 'main' trials, as again the objective results reveal. This explanation may be a tour de force, but it is the only plausible one that we have to offer for *MS*'s results.

No comments were received from *MS* either during or after the experiment. When asked to explain the basis of a particular performance, she always replied, "I don't know." Her behavior was similar to that in the preceding experiments except she stopped more often during the course of the trials and more frequently slapped her face and forehead "to sensitize them." When she collided with the obstacle, she showed surprise and keen disappointment.

Summary

Experiment 3 was conducted to determine whether hearing contributed to the performances of *FB* and *MS* in the preceding experiments; and whether it explained the differences between their results and those of the other *S*s.

FB and *MS* were accordingly deprived of their hearing aids and their ears were so stopped and shielded that they were rendered totally deaf.

Under these conditions, *FB*'s performance was not affected in the least. He perceived the obstacle set in his path in every trial at distances of about 1 ft. The results of this and the proceding experiments with him leave us with the following alternatives: he perceived the obstacle either by means of cutaneous experiences aroused by 'air-' or soundwaves reflected by the obstacle, or by vision. Experiment 4 was planned to test these alternatives.

MS's results were similar to those obtained in Experiment 2 in every respect except one. The discrepancy noted in the proceding experiment between the pattern of her responses in the 'blank' and 'main' trials was not observed in Experiment 3. Under the conditions of this experiment the two samples, the 'theoretical' and the 'observed,' were homogeneous. As far as performance in this study is concerned, loss of the little hearing that she possessed was of no consequence to *MS*. She did as well without it as with it. That does not mean, however, that she did not hear or that hearing did not influence her reports; it merely means that hearing was of no advantage to her in avoiding collisions with the obstacle. A tentative explanation in terms of hearing was offered in explanation of her results.

Experiment 4

Experiment 4 was undertaken to determine whether *FB* perceived the

obstacle in the preceding experiments by means of cutaneous experiences aroused in his cheeks or by means of vision. From his results and behavior and the conditions under which he served, vision was regarded as a distinct possibility. In the present experiment, therefore, we continued the trials under conditions acceptable to him that eliminated entirely the possibility of vision.

Procedure

Efforts to cover his eye that vision would be excluded were unsuccessful. All the usual methods of insuring that he did not see - taping his eye, placing cotton pads over it, using sponge-rubber goggles and other adequate blindfolds - were again tried and again rejected by him as being unsatisfactory. The pressures and tensions aroused in his eyes and face by these methods were distracting and destroyed, as he claimed, the possibility of 'facial vision.'

Because conditions acceptable to him - full exposure of the cheeks and complete freedom of the facial area from distracting pressures - and sufficient to meet the requirements of the present experiment were not to be achieved by any method of covering his eyes that we could devise, we decided to permit him again to wear his blindfold as he wished and to seek the solution in another direction. We finally hit upon a very simple method: conducting the trials with him in the dark when vision, if it were used, would be of no advantage.

We accordingly set the work period at night when darkening the experimental hall would offer no problem. After a few trials in darkness, in which he collided with the screen in every one,[9] he refused to continue and also to serve again at night. His refusal was based on the ground that he was fatigued at night and could do neither himself nor the experiment justice. Night work was accordingly discontinued, but the method of conducting the trials in darkness was not. The hall was darkened by covering the skylights and the trials in darkness were conducted during the daytime.

The hall was as a large darkroom to a light-adapted person but there was sufficient leakage of light from under and around the doors opening into the hall for a dark-adapted person to see his way about it. Two *E*s were consequently used in the experiment. One to conduct *S* to and from the anteroom between successive trials, and the other, who remained in the hall and was dark-adapted, to place the screen at the proper obstacle distance for the various trials and to note *S*'s reports and behavior during the trials. The anteroom was brightly illuminated, hence *S*, if he used vision, would come to the experimental hall light-adapted and the less able to see.

'Blank' trials were used as in the preceding experiments but now *S* was informed that they would be conducted. This change in procedure was found to be necessary because he reported 'first perceptions,' until he was informed of the 'blank' trials, as soon as he was brought to the starting point. (*FB* had learned, during the interval between Experiment 2 and the present experiment, to differentiate the 'first perceptions' from the 'final appraisals.') As a further guard against casual reporting, he was informed whenever he made a 'false' report in a 'blank' trial. The effect of these precautionary measures was to make him more discriminative in giving his reports.

With the exceptions noted, the procedure, instructions, and number of trials were the same in this experiment as in Experiment 2.

Results

Objective

FB was unable to perceive the obstacle under the conditions of this experiment. The exposed cutaneous surfaces were not *sufficient* alone for its perception. As Table IX shows, he collided with the screen in 123 (98 percent) of the 125 trials; in 101 (81 percent) of them before reporting 'first perceptions' and in 22 (17 percent) after the 'first perceptions' without reporting 'final appraisals.' At the shorter obstacle distances (6 and 12 ft), he collided with the screen in every trial before reporting a 'first perception'; whereas at the longer distances (18, 24, and 30 ft) he reported 24 'first perceptions' and 3 'final appraisals.'

His results here are similar to those of the other *S*s in Experiment 2. The averages and deviations of his 'first perceptions' and 'final appraisals' varied directly and the number of his collisions varied inversely with the obstacle distances. That obstacle distance, not the obstacle, was the decisive factor in determining his reports, leads us to conclude that *FB* was guessing and that his reports were matters of chance.

The chance hypothesis is strengthened by his performances in the 'blank' trials. In these trials,[11] he reported 11 'first perceptions' and 3 'final appraisals' - a greater percentage than in the 'main' trials. The pattern of his performance in the 'blank' trials (see Table X) yielded 121 'theoretical' collisions. The 'observed' collisions in the 'main' trials numbered 123. The difference (2) between them and its critical ratio (0.43) are so small that we are warranted in concluding, as in the preceding experiments with the others *S*s, that the two samples are homogeneous. If chance factors determined his reports in one sample - for example, the series of 'blank' trials - they also determined his reports in the other.

TABLE IX

THE RESULTS OF *FB* IN EXPERIMENT 4

Average Distance (in Ft) of *FB*'s 'First Perception' and 'Final Appraisal,' the Performance Ratios, and Number of Collisions for Every Obstacle Distance.

Report	Obstacle-distance (in ft.) 6	12	18	24	30	General average	Collisions No.	Collisions %
First perception (p)	—	—	4.00	7.14	11.85	9.58	101	81
	—	—	±1.00	±4.41	±5.40	±5.68		
Final appraisal (a)	—	—	—	8.00	—	8.00	22	17
	—	—	—	±0	—	±0		
Ratio (p/a)	—	—	—	0.88:1	—	1.20:1		
Collisions							123	98
before (p)	25	25	21	18	12			
after (p)	0	0	4	5	12			

TABLE X

FB's 'FALSE' REPORTS IN EXPERIMENT 4

Number of *FB*'s 'False' Reports, Distribution of the Distances He Walked in 6-Ft Intervals before Making Them, the 'Theoretical' and 'Observed' Number of Collisions, the Difference between Them and the Critical Ratio of that Difference.

Report	No. 'false' reports	Distances walked (in ft.) 1–6	7–12	13–18	19–24	25–30	31–36	37–42	Collisions theo.	Collisions obs.	Diff.	C.R.
First perception (p)	11	0	0	2	3	3	1	2	121	123	2	0.43
Final appraisal (a)	3	0	0	0	2	0	0	1				

Comments and Behavior

Throughout the experiment *FB* reported pressure sensations in his cheeks. They were frequently illusory, however, and he could not tell from them whether the object was present or not. His reports were not guesses; they were always based upon his facial experiences but he could not discriminate the real from the imaginary. At the close of the experiment he wrote as follows:

> "I knew the obstacle to be detected was in front of me - or that it was not. In either event it was necessary to concentrate my attention and effort upon it. Due to anticipation, real or imaginary air currents were drawn across my face and the obstacle always seemed to be in close proximity. At times the facial pressures were so pronounced that I could feel impending danger. At those times I signaled. As subsequent investigation frequently disclosed, however, the pressures were purely imaginal as the obstacle was not present. I believe in those cases that imagination and anticipation of striking the obstacle were so strong that pressures were aroused in my face by the action of my nerves."

FB's behavior was also greatly altered in this experiment. Whereas he had before walked steadily and assuredly at a moderately rapid rate down the hall, he now staggered and went haltingly along the path. He also slapped his cheeks more frequently than before "to sensitize them for the better detection of the reflections," as he explained it. Regarding his behavior during the trials, he wrote:

> "I walk steadily enough when I am in the light, but when darkness comes I lose my balance. I find it difficult to walk in the dark."

Discussion

FB was well aware of his failure in this experiment. That his performances in the preceding experiments were due to seeing the obstacle, he would not, however, admit. He ascribed his present failure, not to the loss of vision per se, but "to the effect that darkness had upon his nerves." He totally lacked vestibular sensitivity, as it will be recalled, hence in darkness he lost bodily stability and his sureness in walking. Darkness made him nervous, tense, and anticipatory which rendered it impossible for him to distinguish the imaginary facial presures from the real.

Since the perception of darkness implies visual experience, *FB*'s explanation is based, in its final analysis upon the doctrine of intersensory dependency - namely, that the loss of light

vision had a deleterious effect upon the pressure sensations in his cheeks. This contention is similar to one examined and found wanting in the earlier study - a braille transcription of which *FB* had at hand - that loss of hearing had a deleterious effect upon the pressure sensations in the cheeks (see Supa, Cotzin, and Dallenbach, pp. 39-42).

FB's explanation of his failure in this experiment is a tacit admission that vision was not excluded in any of the experiments - that it was used in all of them, as we suspected. If his eye had been closed and adequately covered in the preceding experiments, darkness would have been common to all and would not suddenly have entered the picture in this experiment. Darkness or black is, moreover, a visual sensation, hence vision was not completely lost as was the case when audition was eliminated (4, 29, 36, 37, 40, and 41). Although there seemed in general, therefore, little point to *FB*'s contention that his results in this experiment were due to the intersensory dependency of light vision and pressure in the cheeks, we sought in the following experiment to test it.

Experiment 5

Our problem in Experiment 5 was to determine whether loss of light vision - which should have been total in all the experiments, but was total only in Experiment 4 - was responsible for *FB*'s failure in Experiment 4 to perceive the obstacle by means of pressures in his cheeks. Or expressing it positively, our problem was to discover whether pressure stimulation of the cheeks by reflected 'air-' or soundwaves was a *sufficient* condition for the perception of obstacles when light vision was left intact but so shielded that the obstacle could not be seen.

To solve this problem the following requirements had to be met.

1. *S*'s eye had to be left open for light stimulation.

2. It had to be shielded that no light could be reflected to it from the obstacle and the obstacle be seen as a dark shadow when he came close.

3. His cheeks had to be free from distracting pressures and tensions and open to stimulation by reflected 'air-' and soundwaves.

A difficult set of requirements! With the cooperation of *FB*, we finally, however, achieved them.

Apparatus and Procedure

An eye shield was constructed of lightweight, white cardboard (see

Figure 7), the lower front edge of which was cut to the shape of his face. It rested lightly on the bridge of his nose and cheekbones. The front of the shield extended outward about 2 in. at an angle of 45 degrees and then upward about 6 in. Light from above would consequently be reflected into his eye. The sides of the shield, which were the same height as the front, were flat against his temples and extended back to his ears. An elastic band held the shield firmly in place.

The hall was illuminated from above by the sky- and room lights. He held his eye open throughout the course of the various trials.

The procedure, except for the substitution of the eye shield for the blindfold, and the instructions were the same as in Experiment 2. The number of trials, however, were reduced, because of the consistency of his results, to 60 - that is 10 trials at each of the 5 obstacle distances and 10 'blank' trials.

Results

Objective

FB was unable, under the conditions of this experiment, to perceive the obstacle. He collided with the masonite screen, without reporting a 'first perception' or 'final appraisal,' in every trial; and he did not make a 'false' report in any of the 'blank' trials. Although he was seeing, he could not perceive the obstacle by means of pressure sensations in his cheeks.

Comments and Behavior

FB's behavior was similar to that in Experiment 4. Though he could see, he could see nothing but the undifferentiated light from the

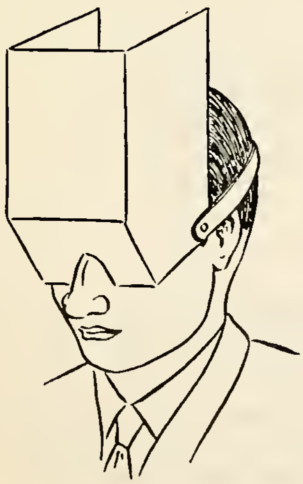

Figure 7. Light Shield Used in Experiment 5.

inside of the shield, hence he had difficulty, since he lacked the organs of the inner ear, in maintaining his balance. He walked staggeringly and haltingly. He again slapped his cheeks, though not as frequently as before.

He reported that he had decided not to guess in this experiment, as he had done at times in the preceding one, but to signal his perceptions only when he was sure the obstacle was in front of him. This self-instruction is doubtlessly responsible for the differences in the results of the last two experiments, as he could see the obstacle in neither of them. At the conclusion of the experiment, he wrote as follows:

> "I found the same difficulty as in the preceding experiment: imaginary air currents floating across my face confused me and made it impossible for me to perform. I knew I did not know, and I would not guess. I could not separate the imaginary from the real.
>
> "I now realize [from the results of the last two experiments] that what I had thought was 'facial vision' was really light perception. Though I cannot see form nor recognize any object, I do perceive light and shade. Because I could not see objects, I had supposed that I was highly proficient in 'facial vision.' When the hall was blacked out so I did not have any light perception, or when my eye was shielded so there would be no variation in my light perception, I flunked. I am now convinced that my ability to move about is due to my light perception and that my successes in the earlier experiments were due to it [that is, to seeing a shadow when about 1 ft from the obstacle].
>
> "I never go out alone at night because I run into difficulties. I have often wondered why. Now I know it is because I cannot use the little vision I have.
>
> "Our experiments this summer prove to me that the deaf-blind do not have, nor will they every be able to learn, the ability to perceive obstacles. Our results reveal that auditory sensation is the basis of the perception and avoidance of obstacles by the blind."

Conclusions

The results of this experiment indicate that *FB*'s failure or inability to perceive the obstacle in Experiment 4 was due, not to an hypothetical, deleterious effect of the loss of his light perception upon the pressure sensations in his cheeks, but to his inability to see it. Because the results of Experiment 4 are corroborated by those in this experiment, we feel justified in concluding:

1. that *FB* was not effectively blindfolded during the first three experiments of this study;

2. that he localized the obstacle during those experiments by means of vision;

3. that his results, when vision was excluded, were not out of line with those obtained from the other *S*s; and

4. that he, in common with the other *S*s, failed to perceive an obstacle when the possibility of stimulation was reduced to the reflection of 'air-' or soundwaves to the exposed areas of the skin, meatuses and tympanums included.

GENERAL SUMMARY

In this study, we sought to discover whether the aural mechanisms, shown in the experiments of 1944 to be the basis of the perception of obstacles by the blind, were auditory or cutaneous. By selecting deaf-blind people with no outer ear defects as *S*s, we eliminated hearing and set ourselves the task of determining whether the cutaneous surfaces of the meatuses and tympanums were *sufficient* to the perception of obstacles.

Conditions were made as favorable as possible for the exemplification of the pressure theory. *S*s were selected who possessed the ability to get about alone to a high degree, and a stone wall which possessed a high coefficient of reflection was used as the obstacle in the first, the exploratory experiment.

In Experiment 1, the *S*s (10 in number) were tested to discover whether they possessed the 'obstacle sense.' One *S* (*FB*) gave indications that he did. He reported the wall in every trial at a distance of about 1 ft. The other *S*s showed definitely that they did not perceive it. Efforts were made, therefore, to teach them. Though they reported 'first perceptions' and 'final appraisals' during the learning trials, their performances showed little or no improvement during the 300 trials given every one of them. The average distances and deviations at which they gave their reports varied directly and the number of their collisions varied inversely with the starting distances. Starting distance, not the wall, was the decisive factor in their reports. Although they gave little indication of learning to perceive the wall, they reported that they learned the floor during the trials and that they judged the position of the wall in terms of the secondary cues derived from it.

In Experiment 2, the secondary cues derived from the floor

were eliminated by substituting a small movable screen for the wall and the *S*s were given 150 trials each to determine whether they had learned anything of the ability in the preceding experiment. The screen was placed at various positions near the center of the hall, while *S* was in an anteroom. When it was in place, *S* was brought to one of several starting points near one end of the hall. 'Blank' trials were introduced to ascertain *S*'s tendency or proneness to guessing.

The *S* (*FB*) who perceived the wall did as well or better than before. He reported the screen at distances over 1 ft, and made no 'false' reports in the 'blank' trials. That he did as well under less favorable conditions - loss of secondary cues from the floor and decrease in the size and reflecting value of the obstacle - placed his results in suspect. The other *S*s did not do as well. The loss of the cues from the floor affected adversely their performances. Though poorer in every respect, their performances varied with the distance of the obstacle from the starting point. Obstacle distance, not the obstacle, was again found to be the decisive factor in determining their reports. With one exception (*MS*), the reports of the *S*s in the 'blank' trials were similar to those given in the trials when the obstacle was present. The results of this experiment clearly indicate therefore that at least eight of our deaf-blind *S*s lack the 'obstacle sense' and are incapable of learning it.

In Experiment 3, the two *S*s (*FB* and *MS*), who wore hearing aids and whose results were out of line with those of the other *S*s, were examined to determine whether hearing contributed to their performances. Their aids were removed and their ears were stopped, rendering them totally deaf, and the procedure of Experiment 2 was repeated.

FB's performances were not affected. As in the preceding experiments, he perceived the obstacle in every trial at distances of about 1 ft, and he did not make a 'false' report in the 'blank' trials. He was either seeing the obstacle as a dark shadow when he came within a foot of it or perceiving it by means of cutaneous experiences aroused by reflections from it.

MS's results were similar to those obtained in Experiment 2 in every respect except one. The discrepancy noted in the preceding experiment - that is, a difference between her performances in the 'blank' trials and the trials in which the obstacle was present - was not obtained in this one. Her performances in the two series of trials were now homogeneous. Although hearing may explain the discrepancy of her performance in the 'blank' trials of Experiment 2, its loss was of no other consequence to her. She did as well without it as with it, which merely means that her performances throughout the study were due to chance. Like the other *S*s, she lacks the ability to perceive obstacles and is incapable of learning it.

In Experiment 4, the possibility of *FB* using vision was eliminated by repeating the procedure of Experiment 2 in the dark. Under this condition, he failed to perceive the obstacle and also to differentiate the 'blank' trials from those in which the obstacle was present. His performances were now similar to those of the other *S*s. The averages and deviations of his 'first perceptions' and 'final appraisals' varied directly and the number of his collisions varied inversely with obstacle distance. It was not the obstacle but the distance from which he started toward it that determined his reports.

Though well aware of his failure in this experiment, *FB* would not admit that his successes in the preceding ones were due to his seeing the obstacle. His explanation was that darkness, with its accompanying loss of light vision, had a deleterious effect upon the pressure sensations in his cheeks. Although this was a tacit admission that vision had not before been excluded in the preceding experiments, we did not argue the point but sought in the following experiment to test his explanation.

In Experiment 5, a cardboard shield was constructed which, when placed on *FB*'s head, reflected light from above into his eye, restricted him from seeing the obstacle, and left his cheeks, meatuses, and tympanums free from distracting stimuli and open to stimulation by reflected 'air-' and soundwaves. With this device, the procedure of Experiment 2 was repeated in the daytime when the hall was well illuminated.

FB failed again. He collided with the obstacle in every trial and was unable to differentiate the 'blank' trials from the trials in which the obstacle was in his path. From his results in this and the preceding experiment, we conclude that he localized the obstacle in the first three by means of vision, and that he, like all of our *S*s, lacked the ability to perceive obstacles and was incapable of learning it.

GENERAL CONCLUSIONS

The results of this study lead us to the following conclusions.

1. Our deaf-blind *S*s, who were selected upon the basis of their ability to get about alone, do not possess the 'obstacle sense' and they are incapable of learning it.

2. The cutaneous surfaces of the external ears (meatuses and tympanums) are not sufficient to the perception of obstacles.

3. The pressure theory of the 'obstacle sense' is untenable.

4. Auditory stimulation is both a *necessary* and a *sufficient* condition for the perception of obstacles by the blind.

5. The problem of this study is answered: the aural mechanism involved in the perception of obstacles by the blind is audition.

6. The auditory theory, sustained by the results of this study, should no longer be regarded as theory but as established fact.

Now that we know that audition is the basis of the perception of obstacles by the blind, our next problem is to determine what auditory dimension (intensity, frequency, volume) is involved.

ACKNOWLEDGMENTS

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We are also deeply indebted to Drs. D. P. Pritchard and David Robb for examining the eyes and ears of our *S*s, and to Dr. Hudson J. Wilson for his assistance in the audiometric tests and loan of his Maico Audiometer.

FOOTNOTES

1. For an excellent summary of the work in this field see S. P. Hayes, reference 14, and reference 16, pp. 49-63. Hayes lists fourteen theories divided into three groups accordingly as they are sensory, perceptual, or occult. The sensory theories postulate an increased sensitivity or heightened response of some of the organs of sense: pressure or temperature in the exposed areas of the skin, principally the face; pressure in

the external auditory meatuses and tympanic membranes; and auditory discrimination and acuity. The perceptual theories postulate that the ability derives from the attachment of new meanings to the usual or ordinary sensory cues. The occult theories explain the phenomena in terms of magnetism, electricity, subconscious, the development of a sixth sense, the vibration of the ether or other hypothetical substance, or the action of vestigial organs ("ocelles") in the skin.

2. The *S*s were chosen by Mr. Bates. He was, within the following limitations, allowed complete freedom in his selection: the *S*s had to be blind and deaf, they had to show a marked ability to move about by themselves, and they had to live within a radius of 300 miles from Ithaca. Mr. Bates was certain that he possessed the 'obstacle sense,' which he thought was a matter of facial pressure, and he chose people from among the group listed with his League who would, as he thought, demonstrate the pressure theory. We had, therefore, a highly selected group of *S*s which was biased, insofar as that was possible, in favor of the pressure theory.

3. For example, *FB* travels alone by train and bus whenever it is necessary. Within the past few years he has been to Denver, Colo., Chicago, Ill., New York, N.Y., Washington, D.C., to say nothing of his lesser trips. *EH* traveled alone from Cincinnati to Ithaca by bus - a 28 hour trip! - to report for the experiments. So also did *CR* from Boston and *GG* and *JG* from New York City. The other *S*s were for reasons of convenience transported from and to their homes by automobile.

4. The case histories were taken by Mr. Bates who could 'converse' with the *S*s by the manual method or in braille as the situation required. He wrote the histories first in braille, so they could be checked and corrected by the *S*s, and then, after that had been done, he typed them for our records.

5. The *S*s were turned clockwise in the rotation chair (1, p. 637 f) in three different positions: (a) sitting upright, (b) sitting with head on knees with frontal plane horizontal, and (c) sitting with head on right shoulder with sagittal plane horizontal. When rotation was abruptly stopped, *S*, in case of position (a), remained in the upright position and his eyes were examined for evidence of nystagmus; in the cases of positions (b) and (c), *S* immediately shifted to the upright position. In all of these instances, *S*'s overt reactions were observed and reports of his after-experiences were taken. *S*'s ability to stand on one foot was explored before he was tested in the rotation chair. If he was unable to stand on one foot, he was spun rapidly around in the chair for 20 sec at the rate of 1 revolution per sec. If he showed normal capacity to stand on one foot, the speed of rotation was reduced to 1 revolution in 3 sec.

6. The wording of these instructions was given careful consideration because the vocabularies of some of our *S*s, particularly of the mutes, was very limited. Only simple nontechnical terms could be used. The instructions given here were written with the assistance of Mr. Bates.

7. Questions upon the instructions were asked the *S*s in braille, by palm printing, and by the manual alphabet. They responded and asked questions of their own by the various means at their command: the mutes by writing on paper pads in long hand or with typewriter, and those who could speak, by word of mouth.

8. Distance in this instance is not, however, the distance between the starting point and the wall. It is rather the distance between the 'first perception' and the wall since the 'final appraisals' are made only in those trials in which 'first perceptions' occur - and in not all of them as collisions occur much more frequently before the 'final appraisals' are made than before the 'first perceptions.' Since, however, the distances of the 'first perceptions' from the wall vary directly with the starting distances, as we have seen, the latter may be used to indicate the former.

9. He collided with the wall in every trial when his eye was closed with adhesive tape or adequately covered with cotton wool. The results of those trials were discarded, however, as the pain aroused by these precautions against seeing was, as he reported, so intense that the delicate pressures by means of which he perceived the wall were submerged. Rather than to press the point about vision in this series of experiments, we permitted *FB* to set the conditions as further experiments (see Experiment 4) were planned that would eliminate vision without discomfort.

10. The differences between the general averages of her 'first perceptions' in the two experiments (9.55 ± 4.76 ft in Experiment 2 and 11.72 ± 5.45 ft in Experiment 3) and of her 'final appraisals' in the two experiments (4.40 ± 2.41 ft and 7.02 ± 2.85 ft, respectively) are small and insignificant - their critical ratios being 0.30 and 0.70, respectively. The difference between the performance ratios in the two experiments (2.17:1 and 1.67:1) is also small, and the number of of collisions is practically identical (73 and 72).

11. Although he knew that 'blank' trials would be given, he did not know how many nor when they would occur. In this connection it should be noted that none of the *S*s in the earlier study, who demonstrated that they perceived obstacles by means of aural cues, fell victim to the 'blank' trials, that is, none of them reported the obstacle when it was not presant (see Supa, Cotzin, and Dallenbach, p. 22).

"FACIAL VISION": THE ROLE OF PITCH AND LOUDNESS IN THE PERCEPTION OF OBSTACLES BY THE BLIND*

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INTRODUCTION

This study on the perception of obstacles by the blind, last of three to be reported from the Cornell Psychological Laboratory, places, as we believe, the final piece in the puzzle presented by the problem of "facial vision." In the first of these studies (Supa, Cotzin, and Dallenbach, 1944, pp. 1-53) upon blind and blindfolded sighted *S*s, the following results were obtained: (1) stimulation of the exposed cutaneous surfaces is *not a necessary nor a sufficient condition* for the perception of obstacles; and (2) *aural* stimulation by reflections from the obstacle is both a necessary and sufficient condition for it. The term 'aural' was used in the conclusions of that study because the aural system, in every series of experiments, was either eliminated entirely or left entirely intact. It was, consequently, impossible to decide from the results at hand whether stimulation of the cutaneous surfaces of the external ears (meatuses and tympanums), as James suggested (18), or audition was the necessary and sufficient condition.

In the second study reported (Worchel and Dallenbach, 1947, pp. 55-112), the deaf-blind *S*s isolated the aural components of the perception. The following facts became evident: (1) the cutaneous surfaces of the external ears (meatuses and tympanums) are not *sufficient* for the perception of obstacles; and (2) auditory stimulation is *necessary* for it. From these results the conclusion was drawn that audition was the basis of the perception.

The next problem which follows logically from these results is the subject of the present investigation - that is, to determine what auditory dimension (loudness of pitch) is involved

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in the perception.

Some of the results of the earlier reports indicate that *S* was dependent upon high auditory frequencies (pitch). In the first study, for example, it was soon discovered that noises, such as made by jingling coins and keys, snapping of fingers, and clicking, hissing, whispering, whistling, and so on, materially aided the *S*s. They were consequently forbidden during the experimental trials to make those noises (see Supa, Cotzin, and Dallenbach, p. 33 and footnote 1, p. 51). Similar indications were obtained in various experimental series of that study. In Series A, of Experiments 1 through 3, *S* walked over a hardwood floor wearing shoes; in Series B, of the same experiments, he walked upon a carpet runner in stocking feet. His performance in Series B was poorer than in Series A (see Supa, Cotzin, and Dallenbach, pp. 15, 17-18, 21-22, and 24-26): the decrement was thought to be due to the loss of the high-frequency noises aroused in Series A by the click and shuffle of *S*'s shoes on the floor. In Experiment 7, in which *S*, from a soundproof room, judged the experimenter's (*E*'s) approach to an obstacle in a distant room by means of the sounds of *E*'s footsteps which were picked up by a microphone, carried by *E* at ear-height, and transmitted to *S* through an amplifying set and earphones whose upper limit of fidelity was 12,000 Hz, *S*'s performance was not as accurate as when he himself approached the obstacle. The absence of the higher audible frequencies in this transmission system, noted and reported by all the *S*s, may have been in part at least responsible for the poorer performance (see Supa, Cotzin, and Dallenbach, pp. 45-47 and footnote 11, p. 52).

The inference that high frequencies play an important role in the perception of obstacles by the blind was also supported by the results of the study with deaf-blind *S*s (see references 10 and 11, and Supa, Cotzin, and Dallenbach, pp. 50-51). Two of the *S*s serving in that investigation wore hearing aids. As indicated by audiometric tests, neither could hear by bone conduction at intensifications up to 120 dB; but, with their hearing aids, one had an auditory range of 128 to 2896 Hz at 60 to 90 dB intensification and the other a range of 64 to 5792 Hz at 20 to 60 dB. Neither, however, possessed the 'obstacle sense' and neither was able to learn it even with hearing aids in place. Apparently the ability to detect and to avoid obstacles depends upon audible frequencies higher than the upper limits of these *S*s' ranges (see Worchel and Dallenbach, pp. 61-63, 66-67, 96, and 106).

Because of the results reviewed above, first to be considered in the present study was the role of auditory frequency in the perception of obstacles by the blind.

METHOD AND PROCEDURE

The most direct approach to the solution of this problem would be to transmit to an *S*, who possessed the ability to perceive obstacles, a noise that contained all the audible frequencies at high intensity and to move it toward an obstacle at a controlled rate. After it had been determined that *S* could detect the obstacle with this stimulus, and norms of performance had been established, the particular range of frequencies essential to the perception could be determined by repeating the trials with various band filters - beginning with a low-pass band and working gradually and systematically upward through the audible range.

This method was, unfortunately, denied us because it was impossible to obtain the necessary equipment at the time this study was being made. (The study was made during the spring and summer of 1942 when it was impossible, due to war shortages, to obtain apparatus except with high priority and for war use.) Another method of attacking the problem had, therefore, to be devised. Since the purpose of using band filters was merely to present tones of known and controllable frequencies, we might, as we thought, accomplish the same result by using pure tones and presenting them separately to *S* - apparatus for the production and registration of which we had at hand. The chief difference between the two methods, beyond the matter of implementation, was the complexity of the auditory stimuli. With band filters, the stimuli would be a narrow band of frequencies; with pure tones, a single frequency would serve as the stimulus. Pure tones with stimuli of single frequencies might fail to yield the perception, a possibility we had to take into account; but if *S* succeeded in perceiving obstacles with a pure tone as the stimulus, we should know definitely that a complex auditory pattern was not a necessary condition for the perception. By using pure tones we should be taking two experimental steps at once - that is, resolving the problem of frequency and complexity at one and the same time.

To present pure tones as stimuli, we proposed to use a modification of the method and procedure of Series 7 of the first study (see Supa, Cotzin, and Dallenbach, pp. 42-47). In this series as it will be recalled, *S* from a soundproof room judged the experimenter's (*E*'s) approach to an obstacle by means of the sounds of *E*'s footsteps which were picked up by a microphone, carried by *E* at ear-height, and transmitted to *S* through a high-fidelity amplifying set and earphones. All of the *S*s serving in the series were able to perceive *E*'s approach, and their ability to do so was not greatly inferior to their own performance when they themselves walked toward the obstacle.

Their decrease in performance was in part explained, as stated above, by the absence of the higher audible frequencies in the transmission system which had a ceiling of about 12,000 Hz. It could also be explained in part by *S*'s lack of aids

that were his when he himself did the walking. *E* had to walk toward the obstacle with uniform steps (rate and tread). For him to have done otherwise would have invalidated the results. If *E* had, for example, slowed, shortened, or loudened his steps as he neared the obstacle, he would have introduced extraneous criteria. When *S* walked toward the obstacle he was permitted to do all those things. At critical points in his progress, *S* could and did slow his approach, or stop, or back up a little and pass through the critical point again, or shuffle his feet, or tread heavily or lightly - all of which are serviceable aids in his performance. *S* should have the same freedom in the present experimental situation as he had when he himself did the walking. Anything short of that would be to place him under an additional handicap.

There was nothing we could do to increase the upper range of our transmission system - that was a limitation that we had to accept in this study; mayhap it would suffice. We could, however, as we thought, devise some method of giving *S* control of the advancing stimulus. He should be able from his observational station within the soundproof room to regulate the movement of the sound toward the obstacle - that is, to stop it or to move it at a rate of his choosing.

Apparatus

To meet the requirements of this study we sought to devise an apparatus that would meet the following specifications.

1. The movement of the sound stimulus should be controlled by *S*, who should be able to accelerate, decelerate, or stop it as he wished.

2. The rate of movement should be capable of being varied from 0 to 6 ft/sec - that is, from stop to speeds greater than normal walking.

3. *E* should be able to switch off *S*'s perception and control of the movement of the stimulus and to control the movement of the apparatus himself so that it may be returned between successive trials to a new starting point.

4. The carriage upon which the sound source (a high-fidelity loudspeaker) and the pickup microphone are mounted should move noiselessly. No sounds other than those arising from the loudspeaker should be present in the experimental room.

Various attempts were made to construct apparatus to meet these specifications. It was through our failures, however, that we finally achieved success.

A toy electrical locomotive was first tried as a means of

satisfying these specifications. The ease and convenience by which its rate and direction of movement (Specification 1) could be controlled recommended it, but ease and convenience are poor experimental guides! We were unable to meet Specification 4; we could not eliminate the burr of its motor nor the clatter of its wheels upon the tracks.

We then turned to the construction of a wooden runway. This was smoothed and waxed and over it a waxed, wooden block carrying a loudspeaker and a microphone was drawn by a system of chalk-line belts and fiber pulleys and a reversible motor. We first elevated the runway from the floor and mounted the microphone on the waxed carriage at ear-height and the loudspeaker near the floor - the usual position of the sound source. The possibility that the supports of the runway would interfere with and differentially reflect the soundwaves as the carriage was moved toward the obstacle (the end wall) caused us to change the construction and to suspend the runway from the ceiling. Here again the microphone was placed at ear-height but the loudspeaker was placed above it at the same distance that it had previously been below it. Though the sound now came from above the microphone, the soundwaves struck the obstacle at the same angle of incidence, with respect to the point of pickup, as a sound from the floor.

To make the necessary electrical connections with the microphone and loudspeaker we proposed to run copper wires along the runway and to make contact by spring brushes attached to the carriage. When the wires were being put into place, the dispensability of the wooden runway became apparent. The wires, intended for the electrical circuits, would themselves serve as the runway if they were strong and tautly stretched.

The wooden runway was therefore abandoned and three steel wires (No. 16 piano wires) were run the length of the experimental room (the large hall used in the preceding studies, 18 ft wide, 61 ft long, and 20 ft high with beamed, center-ridged ceiling and two skylights), 10 ft above the floor. These wires, 3 in. apart, were stretched tautly and anchored to heavy steel brackets attached at the end walls to a 2-in. steel air-pressure pipe that ran through the center and length of the hall. Near the middle of the hall - 35 ft from the wall used as the obstacle in the experiments - a bridge, supported from one of the cross beams in the ceiling, was constructed to take up the sag in the 61-ft span.

A carriage - a block of wood 1 in. thick, 8 in. wide, and 12 in. long - was suspended from the wires and a loudspeaker and a microphone were attached to it. The loudspeaker was immediately beneath the carriage and the microphone, by means of a long bracket, was placed 5 ft 3 in. from the floor, the height of the ears of the average person. The forward edge of the loudspeaker and the cone of the microphone were in the same perpendicular

plane. The weight of the carriage and attached apparatus was 10 lb.

The carriage was moved along the wires by means of a variable speed, reversible, dc motor and a chalk-line belt. The belt ran from the motor through noiseless, fiber pulleys to the two ends of the carriage. The motor was placed, to eliminate its noise, in a soundproof box with its shaft and a 2-in. drive wheel projecting to the outside.

The speed of the motor was controlled by two rheostats: one (A) on the motor box and the other (B) at *S*'s station in the soundproof room. Rheostat B was operated by *S* by means of a foot pedal. Rheostat A on the motor box was so set that the motor at maximal speed drew the carriage along the wires at the rate of 4 ft/sec, slightly faster than the normal rate that a blind *S* walked toward the wall. From this upper limit, the speed could be varied downward to cessation by *S*'s rheostat. Although *S* could control the speed as the carriage approached the wall, he could not reverse its direction of movement. Direction of movement was controlled by *E* at his desk by means of a commutator.

A wiring diagram of this part of the apparatus is shown in Figure 1. The dc power line connects to Terminals 2 and 3 of the motor and leads to a commutator on *E*'s desk. Thence the current goes through Switch K, also on *E*'s desk, to Rheostat B at *S*'s station in the soundproof room and then back through Switch K to Rheostat A on the motor box and to the motor. When Switch K is at pole 'a,' *S*'s rheostat is out of the circuit and the motor is subject alone to *E*'s control. It rotates forward or backward accordingly as the commutator is at 'x' or 'y' and at the maximal speed determined by the setting of Rheostat A. When Switch K is set at 'b' and the commutator at 'x,' the motor moves the carriage forward at a rate, within the limits of 0 to 4 ft/sec, determined by *S* by means of Rheostat B.

Various means were used to support the carriage from the wires. Suspension from wheels was first tried. Though we used wheels of different materials (metal, wood, fiber, rubber) and

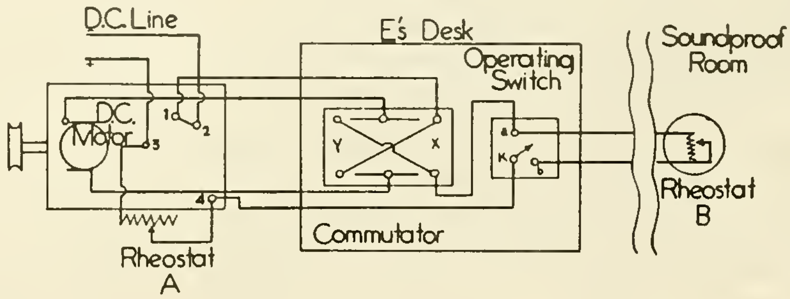

Figure 1. Wiring Diagram of Apparatus Controlling Direction and Speed of the Moving Stimulus.

different sizes (from large to small), we were unable to eliminate the accompanying noises - that is, to meet Specification 4. Wheels were therefore given up and the carriage was suspended by oil-soaked rope. For a short time this was successful but soon the movement of the carriage was again accompanied by noise.

Our problem was finally solved by using wooden supports. Two soft pine bars, of length equal to the width of the carriage, were boiled in paraffin for an hour. Three grooves, each 1/4 in. wide and 1/2 in. deep, were cut into these bars at intervals of 3 in. - the separation of the suspension wires. Holes (1/4 in.), bored at the centers of every groove, were filled with wicking to serve as oil wells. The supporting wires were placed in these grooves and the bars were screwed to the top ends of the carriage. The oil wells, frequently filled, kept the wires well lubricated with the consequence that the carriage could be moved smoothly and noiselessly. Our specifications had been met.

Stimuli

The stimuli used in this study were thermal noises and pure tones. They and the devices for producing them are described in detail when the experiments in which they were severally employed are reported.

Accessory Apparatus

The accessory apparatus consisted of the loudspeaker and the microphone mentioned above, a power amplifier, an attenuator, a set of high-fidelity headphones for *S*, and two communicating systems between *E* and *S*.

The stimuli, thermal noises or pure tones, were transmitted from the apparatus producing them over wires suspended from the moving carriage to a 110-V ac cone loudspeaker. The loudspeaker was incased in a small wooden cabinet (8 in. wide, 10 in. high, and 10 in. long) with its diaphragm (5 in. in diameter) toward the obstacle. The cabinet was attached to the bottom of the carriage and was insulated from it by rubber cushions that vibrations from the loudspeaker would not be communicated to the carriage and supporting wire cables.

The microphone, an Astatic T-3 semidirectional crystal microphone whose frequency response was uniform from 30 to 10,000 Hz, and whose output level of -52 dB (below 1 V/bar) was ample in connection with our high-gain amplification, was attached to the bottom of the cabinet of the loudspeaker by a wooden bracket that brought it to ear-height (5 ft 3 in.) from the floor. It was taped to the bracket and isolated from it by sponge rubber so that no vibrations from the loudspeaker would be communicated through the bracket to it.

Its forward point was in line with the front of the loudspeaker. To protect it and the loudspeaker from collisions with the obstacle, a rubber-tipped bumper, projecting 2 in. beyond this forward line, was attached to the bracket at a point 6 in. below the cabinet.

The microphone was connected to the power amplifier by a standard shielded cable which was also suspended from the moving carriage.

The cable from the microphone was connected to the input of a No. 19 Stromberg Carlson 22-W amplifier. The frequency response of the amplifier was 30 to 10,000 Hz with not more than 3 dB variation. Its power gain was 119 dB from the microphone input and any distortion was reduced by means of a multistage inverse feedback circuit. The hum and noise level was 50 dB below the maximal signal whereas a treble suppressor enabled *E* to control the output.

An attenuator was placed in the circuit between the amplifier and *S*'s earphones. This instrument, which afforded a wide range of attenuation (93 dB), was placed in the sound transmission system to control the loudness of the stimuli perceived by *S* and also to provide a means of determining *S*'s intensive limen. (For a description of the attenuator see reference 8.)

The headphones, worn by *S* in the soundproof room, were connected to the attenuator. They were the Brush High Fidelity Model, Type A-1, whose range was 100 to 12,000 Hz. These phones possessed high impedance hence the disturbance in the critical electrical circuit was minimal.

Two systems were used for communication between *E* and *S*; one was telephonic and the other a bell-buzzer annunciator. *S* had a telephone transmitter which was connected to a set of earphones worn by *E* in the experimental hall. By this means *S* could talk to *E* and give his reports during and after the trials. *E*'s replies, merely spoken at conversational intensity in the hall, were picked up by the microphone and transmitted to *S* through the headphones worn by him. This means of communication was supplemented by a bell and buzzer system. The bell, on *E*'s desk, was rung by a push button on *S*'s desk; and the buzzer, on *S*'s desk, was sounded by a push button on *E*'s desk.

Subjects

Four *S*s, two blind and two with normal vision, served in all of the experiments in this study. The blind were Mr. Edward Smallwood (*SB*), a senior in the Arts College of Cornell University, and Mr. Richard Flight (*FB*), a recent graduate from Ithaca High School and an accomplished musician whose occupation was piano tuning. The sighted *S*s were Miss Patricia Cain (*CS*), graduate

fellow in psychology, and Mr. Frederick Marcuse (*MS*), graduate assistant in psychology.

For the convenience of the readers, the symbols used for the *S*s indicate whether they are blind or sighted. The first letter of the two-letter symbols is the first letter of *S*'s last name; the last letter, *B* or *S*, indicates blindness or sightedness.

SB and *CS* had both served as *S*s in the experiments of the Supa, Cotzin, and Dallenbach study and are designated in that study by initials *ES* and *PC*. *FB* and *MS* were inexperienced in this type of work. *SB* had been blind since early childhood; *FB*, for the past 14 years. Both of the blind *S*s possessed the ability to detect obstacles and both, though possessing 'seeing eye' dogs, used that ability constantly in their daily lives. Of the two sighted *S*s, *CS* had acquired the ability during the earlier study but *MS* lacked the ability and, though willing to serve, was extremely doubtful about his being able to acquire it.

Before the experiments were begun, the eyes of the blind *S*s were examined by an oculist and audiograms were made for all the *S*s by a Maico Audiometer.

The following reports were received from the oculists regarding the eyes of our blind *S*s.[1]

FB

Age: 22 years

History: Injury to right eye when 9 years old by a wire. Sympathetic ophthalmia followed in left eye.

Examination: O. D., no vision. O. S., small section of upper edge of cornea almost clear. When light jets in, he can see a moving object.

Opinion: Condition of O. S. due to scar tissue from inflammation.

SB

Age: 22 years

History: Eyes normal until 5 years of age at which time right eye was injured with a knife. Sympathetic ophthalmia followed in left eye. Right globe enucleated.

Examination: O. D., globe removed. O. S., phthisis bulbi; no light perception whatever.

Opinion: Destruction of right eye by injury and resulting

infection requiring enucleation. Almost complete destruction of left globe following a sympathetic ophthalmia.

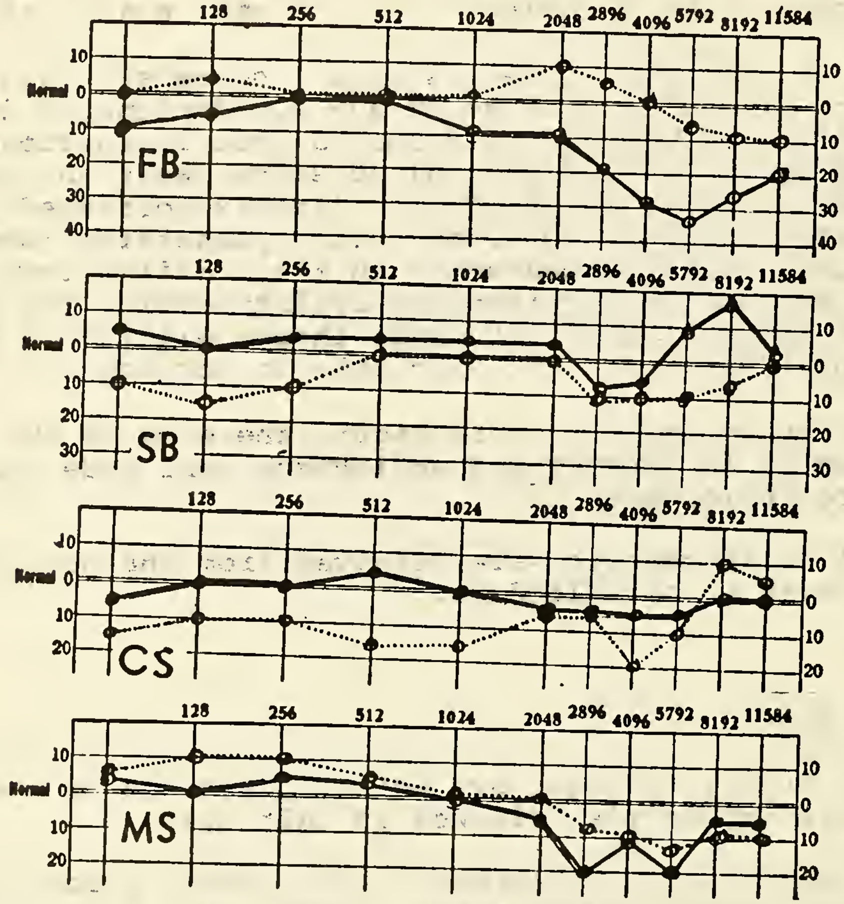

Figure 2. Maico Audiograms of the Ss. (Solid lines, right ear; dotted lines, left ear.)

The Maico audiograms of the *S*s for pure tones from 64 Hz to 11,584 Hz are shown in Figure 2. The solid line shows the results for the right ear, the dotted line for the left. Since it has been demonstrated that performance in the perception of obstacles is as accurate under monaural as binaural stimulation (34), the range of *S*'s better ear is alone of significance. As the audiograms show, the better ears of all the *S*s are at or better than normal for the lower frequency ranges and, with one exception (*MS* at 5792 Hz), the losses at the upper levels are 10 dB or less. *SB* has better than normal hearing at the three highest levels, and *CS* at the two highest.

Training

Preliminary Training

All the *S*s were given preliminary training. The *S*s (*SB* and *CS*) who had served in the earlier study were given it to determine whether they still perceived obstacles with the efficiency they had previously shown and, if not, to bring them through practice to that level. The *S*s new to this work (*FB* and *MS*) were given it for several and different reasons. *FB* was given it to discover whether he could utilize under experimental conditions the ability to perceive obstacles which he possessed in everyday life; and *MS*, to determine whether he could learn without vision to perceive obstacles in his path. We also wished to determine, in case the new *S*s were successful, whether the aural mechanisms were the necessary and sufficient conditions for their perceptions. In addition, we wished to obtain norms of performance for all the *S*s that we should have data with which to compare directly the results of the main study.

Training Series

With the exception of Experiment 2 and Series B of Experiments 1, 3, 4, and 5, in which the *S*s walked on carpet runners in their stocking feet, all the experiments of the first study were repeated with our *S*s (see Supa, Cotzin, and Dallenbach, pp. 9-49). The procedures of the various experiments were followed faithfully but the number of trials was reduced for *SB* and *CS* when it became evident that these *S*s had lost none of their ability to perceive obstacles.

Results

The results of *FB* and *MS* in the Training Series are shown in Table I which gives the number of trials made in every experimental situation, the averages of the 'first perceptions' and of the 'final appraisals' of the obstacle, the ratio of these averages, and the number of collisions. For purposes of comparison with the other *S*s and with results of the main study reported below, the results of *SB* and *CS* in the first study are also given. As this table shows, the results of the Preliminary Training experiments corroborate those of the earlier study. Not only did the new sighted *S* (*MS*) rapidly acquire the ability to perceive obstacles but both he and the new blind *S* (*FB*) showed, in conformity with the *S*s of the earlier study, that the aural mechanisms were the basis of their performance.

We were now ready with adequate apparatus and competent *S*s, trained in observation and skilled in report, to turn to the problems of the present study.

TABLE I

RESULTS OF PRELIMINARY TRAINING

Showing for Every Experiment the Number of Trials, the Average Distance from the Obstacle of the 'First Perceptions' and the 'Final Appraisals,' the Ratio of These Averages, and the Number of Collisions.

S	Experiment	No. of trials	Average distance (in ft.) (A) 'first perceptions'	(B) 'final appraisals'	Ratio A/B	No. of collisions
FB	1	27	5.76± .91	.50±.07	11.52	2
	3	25	7.30± .79	.50±.08	14.60	0
	4	27	7.00± .99	.50±.17	14.00	2
	5	50	—	—	—	50
	6	50	—	—	—	50
	7	27	4.84±1.20	1.12±.44	4.32	2
*SB**	1	25	18.04±6.69	.52±.04	34.70	0
	3	25	17.08±6.96	.50±.00	34.16	0
	4	25	8.56±1.94	.62±.18	13.80	0
	5	50	—	—	—	50
	6	50	—	—	—	50
	7	26	10.20±1.12	2.74±.34	3.72	1
*CS**	1	40	2.12± .80	.56±.10	3.79	15
	3	26	3.34±2.13	.84±.34	3.98	1
	4	30	1.44± .81	.70±.30	2.06	5
	5	50	—	—	—	50
	6	50	—	—	—	50
	7	28	6.60±2.77	1.60±.24	4.12	3
MS	1	37	1.97± .62	.62±.08	3.18	12
	3	27	1.74± .84	.54±.09	3.22	2
	4	27	2.37± .54	.88±.29	2.70	2
	5	50	—	—	—	50
	6	50	—	—	—	50
	7	26	3.16±1.09	.64±.35	4.94	1

* The results of these *S*s were taken from the earlier study made by Supa, Cotzin, and Dallenbach.

PROBLEM

Although our first problem was to determine at what audible frequencies *S* could detect the wall, we had to know, before we could consider that problem, whether continuous sounds were adequate to the perception of obstacles. The plan of our procedure in this study rested upon the assumption that continuous sounds were adequate, but until we knew definitely that that was the case we should be unable to interpret our results - particularly if they were negative. It might be, if our results were negative, that *S*'s failure to detect the obstacles was due to the continuity of the sounds rather than to their frequency. We, therefore, conducted the following series of Preliminary Experiments to resolve this problem.

PRELIMINARY EXPERIMENTS

Experiment 1

In all the instances and experiments in which *S walked* toward an obstacle, and in Experiment 7 of the earlier study, in which *S* judged *E*'s approach to an obstacle by the sounds of *E*'s footsteps, the sounds serving as the basis of *S*'s judgments were intermittent, discontinuous noises. Our first problem was, therefore, to determine whether *S* could detect obstacles when the stimuli were continuous instead of intermittent, and, if so, how his judgments under these different conditions compared.[2]

Method

Stimuli

A thermal noise was used as the stimulus. This noise was produced by a five-stage resistance-capacity coupled push-pull amplifier and transmitted to the loudspeaker attached to the moving carriage (35). (Our thanks are due Professor G. L. Kreezer for his assistance with this apparatus.) The input resistance at which the noise was generated was 1 MΩ connecting the grids of the two input tubes. An oscillogram of the thermal noise used, which was made by a DuMont Type 208 Cathode-Ray Oscilloscope at *S*'s headphones (the headphones were disconnected and the oscillograph was put in their place) after it had been released by the loudspeaker, picked up by the microphone and transmitted through the amplifier to *S*'s station, is shown in Figure 3. The wave pattern is highly complex and all the audible frequencies are present at approximately equal intensity.

Figure 3. Oscillogram of the Thermal Noise Used as the Stimulus in Experiment 1.

The loudness of the thermal noise was varied among the *S*s according to their own intensity preferences. It was set by means of the attenuator at 66 dB above the limen for *FB*, 43 dB for *SB*, 35 dB for *CS*, and 46 dB for *MS*. The loudness once selected by *S* was held constant for him throughout the experiment.

Instructions

The following instructions were given *S* before every experimental period.

> "When you hear the stimulus sound, depress the foot-pedal. This will cause the sound to approach the wall as slowly or as rapidly as you wish because the speed is controlled by the depression of the foot-pedal. The greater the depression the greater the speed. When you perceive the obstacle, stop the approach by releasing the pedal and report to *E*. After you have reported, move the stimulus forward again until it is as close to the wall as you can possibly bring it without colliding with the wall, and report to *E*. The sound will then cease and you may relax until you hear it again, which is the signal for another trial. During the course of a trial watch for changes in the sound."

Procedure

S was comfortably seated in an easy chair in the soundproof room with headphones over his ears, the telephone transmitter through which he communicated with *E* in his hand, and with his right foot upon the footpedal rheostat which controlled the movement of the stimulus carriage.

Between trials, while *E* set the apparatus for the next run, the output plug of the attenuator was disconnected so that *S* would hear nothing from the experimental room. *S* had, therefore, no cues regarding the starting position of the stimulus carriage which, unknown to him, was placed at one of four starting points: 6, 12, 18, or 24 ft from the obstacle. These points were used in a planned haphazard order which guaranteed that every point was used as often as every other and without any given sequences.

After the carriage had been run back to the planned starting point and the rest of the apparatus set in appropriate order, the output plug of the attenuator was connected and the sound from the loudspeaker was heard by *S*. The sound was itself the signal that the trial had begun and that *S* should depress the footpedal and bring it to the obstacle. After every trial, whether *S* was successful or not in perceiving the approach, this procedure was again repeated.

Twenty practice trials were given every *S* before the main trials (40 successful trials, 10 from each of the four starting points) were conducted.

The end wall of the experimental room, a 4-ft stone wall, hard

plastered and decorated with semigloss paint, was at first used as the obstacle. We chose it because it was large and offered a highly favorable reflecting surface for soundwaves. After a few preliminary trials, however, we abandoned it for a movable screen.

Though *CS*, our pilot *S*, was highly successful in her judgments of the wall under these conditions - her 'first perceptions' averaged about 6 ft and her 'final appraisals' about 3 in. - the change was made to a movable screen because of her observations. She reported that she based her judgments upon changes in the pitch of the stimulus sounds; that the pitch suddenly began to raise at a certain point and that it continued to raise until shortly before the collision with the obstacle. Her 'first perceptions' were marked by the initial rise in pitch and her 'final appraisals' by the cessation of the raise. When her observations were verified by both of the *E*s, the following questions arose. Is the rise in pitch an artifact of the conditions; or is it due to changes inherent in the approach of a sound to an obstacle? Do the suspension wires produce audible sounds when, like a fretted string, the distance between the moving carriage and the anchor on the end wall becomes 6 ft or less? Or, do these wires, as the terminal distances become shorter and shorter, vibrate in resonance with higher and higher frequencies of the thermal noise? These questions had to be considered and answered before the experiment could be continued with the other *S*s.

If the rise in pitch was artifactual - that is, due to the shortened length of the suspension wires - then a large obstacle placed in the 'runway' beneath the wires at distances greater than 6 ft from the wall should eliminate it. If, on the other hand, the rise in pitch was inherent in the approaching noise, then the intervening obstacle should not affect it. We therefore substituted a movable screen - a 1/4-in. masonite board, 4 ft wide and 7 ft 4 in. high - for the wall. This was placed in the 'runway,' 6 to 12 ft in front of the wall. Its lower edge was 14 in. from the floor and its upper edge was 3 in. below the suspension wires - above the level of the diaphragm of the loudspeaker.

When the trials were repeated under these conditions, the rise in pitch was noted as before. *CS*'s 'first perceptions' and 'final appraisals' were again based upon her perception of the changes in pitch of the stimulus noise. We concluded, therefore, that the pitch changes were inherent, that they were due to the presence of an obstacle. We could, therefore, have returned to using the end wall as the obstacle, but we continued to use the movable screen though it was not as large nor its coefficient of reflection as good as the end wall. It was placed, unknown to *S*, in haphazard order at 6 and 12 ft before the wall.

Results

All the *S*s were successful in perceiving the obstacle and in bringing the stimulus noise close to it whether it was placed 6 or 12 ft in front of the end wall. Their results are given in Table II which shows the number of trials required for 40 successes, the averages of the 'first perceptions' and the 'final appraisals' of the obstacle, the ratio of these averages, and the number of collisions.

TABLE II

RESULTS OF EXPERIMENT 1

Showing the Number of Trials Required for 40 Successes, the Average Distance from the Obstacle of the 'First Perceptions' and the 'Final Appraisals,' the Ratio of These Averages, and the Number of Collisions.

S	No. of trials	Average distance (in ft.) (A) 'first perceptions'	(B) 'final appraisals'	Ratio A/B	No. of collisions
FB	43	3.20 ± .95	.60 ± .13	7.11	4
SB	44	5.40 ± .41	.76 ± .15	5.33	3
CS	40	4.40 ± .70	.65 ± .10	6.77	0
MS	42	2.03 ± .49	.65 ± .12	3.12	2

All the *S*s noticed the rise in pitch of the thermal noise as it approached the obstacle and they based their judgments of the position of the stimulus noise in relation to the obstacle upon it. Representative reports received during the course of the experiment are quoted below in evidence.

FB

"After a time I noticed a change in pitch. The rise is continuous up to the wall. If I had absolute pitch, I could stop it within an inch of the wall every time."

SB

"The sound changes in pitch, the intensity is constant. All I have to do is to listen for the first and last pitch change and I can do it."

CS

"The pitch rises. The hissing sound becomes higher

when the wall comes in, and continues to rise until it gets very close to the wall. I make my judgments on the basis of the pitch changes."

MS

"For my first perception I listen for a new sound to come in - a sort of siren effect. In judging the near approach, I try to stop the movement when the sound is at its highest pitch. This is not easy to do. If I delay in my judgment too long, the wall is bumped; if I am hasty, I might have been able to do better had I delayed."

From the results of this experiment it is quite evident that continuous sounds are as adequate as discontinuous sounds in the perception of obstacles. Indeed, as a comparison of the performances of our *S*s - as that is measured by the ratios of the 'first perceptions' to the 'final appraisals' - in this and the comparable experiment (Experiment 7) of the Preliminary Training Series shows, three of our *S*s (*FB*, *SB*, and *CS*) did better when the thermal noise was used than when *E*'s footsteps were the source of the stimulus sounds. One (*MS*), the least experienced and the least practiced of our *S*s, did, on the contrary, slightly poorer. He had difficulty, as he reported, with the higher frequencies of the thermal noise. "This is not easy," he said in one of his reports, "because it is detecting differences at frequencies higher than those in the footsteps."

Summary

The superiority of performance with the thermal stimulus may be due to one or to both of the following reasons.

1. Continuous sounds may be superior to intermittent in the detection of obstacles. This explanation is plausible as the opportunity to detect changes in a continuous stimulus is present all the time and the approach may be stopped at any point. When the stimulus is intermittent, the opportunity to detect changes is periodic - that is, is present only when the stimulus occurs - and the approach is stepwise and cannot be stopped at points intermediate between successive steps.

2. The thermal noise may be superior, as a stimulus in the detection of obstacles, to the sounds of footsteps. This explanation is also plausible since the thermal noise contains more audible frequencies and at a higher intensity level than the sounds from footsteps. The composition of the thermal noise is, moreover, constant from moment to moment and from trial to trial. The sounds of footsteps, contrariwise, may vary from step to step, depending upon fortuitous conditions such as the force, place, and angle of incidence of the tread. One footstep may contain fre-

quencies that the next one lacks.

We have no basis in this study for a decision between these explanations. It seems probable, however, that both are effective in the results of this study.

Experiment 2

Although our *S*s, in Experiment 1, judged 'first perceptions' and near approaches when a continuous sound was used as the stimulus, and reported that their judgments were based upon changes in the pitch of that sound, we cannot be certain, short of an experimental demonstration, that that was the case. It may be that their judgments were based upon minimal cues, derived from the movement of the carriage, that had remained marginal and had not come to their nor to *E*'s attention. Until this possibility was investigated, we could not safely proceed to the Main Experiments. We undertook, therefore, to determine in the present experiment whether *S* could judge the position of the carriage in respect to an obstacle from its movement alone.

Method

The procedure of Experiment 1 was repeated with the exception that the loudspeaker was disconnected. It was silent as the carriage was moved by *S* along the suspension wires.

Every *S* was given 40 trials. Scattered haphazardly among these trials, various check experiments were introduced. *E*, unknown to *S*, so set the commutator that the carriage remained stationary or moved away instead of toward the wall when *S* depressed his footpedal. The beginning of every trial was designated by a signal on the buzzer.

Results

None of the *S*s could render a judgment regarding the position of the carriage in respect to the obstacle in any of these trials; and none was able to differentiate between the check experiments (in which the carriage remained stationary or moved away from the obstacle) and the normal trials (in which the carriage moved toward the obstacle). Collisions between carriage and obstacle were frequent and in the few instances in which they were avoided, the reports were sheer guesses as the *S*s readily admitted.

These results indicate that the reports in Experiment 1 were based upon the continuous sounds from the loudspeaker and they confirm the conclusion drawn above that continuous sounds are as adequate as intermittent sounds in the perception of obstacles - if, indeed, they are not superior.

We are now prepared to turn to the first of our main problems.

MAIN EXPERIMENTS

Experiment 3

With the knowledge that continuous sounds were adequate to the perception of obstacle - were equal or even superior to intermittent sounds - we sought in Experiment 3 to determine the role of frequency (pitch) in the perception.

Method

Stimuli

The procedure of Experiment 1 was repeated with pure tones being as the stimulus sounds instead of the thermal noise. Eight pure tones, falling within the audible range covered by our apparatus, were selected. Their frequencies were: 125, 250, 500, 1000, 2000, 4000, 8000, 10,000 Hz. They were generated by an RCA Beat-Frequency Oscillator (No. 154) whose frequency range was from 30 to 15,000 Hz. The oscillator was operated from an ac source of 110 V and 35 W. This unit was stable after it was turned on and warmed for about 30 min. Distortion was less than 5 percent over the entire frequency range. With a load impedance of 5000 Ω, the variation of the output was ±1 dB or less.

Oscillograms of the wave forms of these tones are shown in Figure 4. They were made with the oscilloscope being substituted for *S*'s headphones. They show the wave form delivered at the headphones. Up to this point there is no distortion of the tones of the oscillator by the loudspeaker, the microphone, the transmission and amplifying system.

Oscillograms of the tones as heard by *S* - that is, after they had passed through the headphones - were made by connecting one of the headphones to the oscilloscope and picking up with it the tones transmitted by the other headphone. All the oscillograms obtained by this method, two of which are reproduced in Figure 5 (tones of 250 Hz and 500 Hz), show our tones riding upon a 60 Hz wave. That this wave was picked up by the headphones was evident from the fact that it was not present when the headphones were not in the circuit, and by the further fact that it was present when the headphones, apart from the circuit, were connected alone to the oscilloscope. Though shielding the headphone and its leads to the oscilloscope would doubtlessly have eliminated the 60 Hz wave, we did not believe that that was necessary because:

1. the headphones did not transmit frequencies much below 100 Hz;

2. the 60 Hz wave was inaudible over the phones when

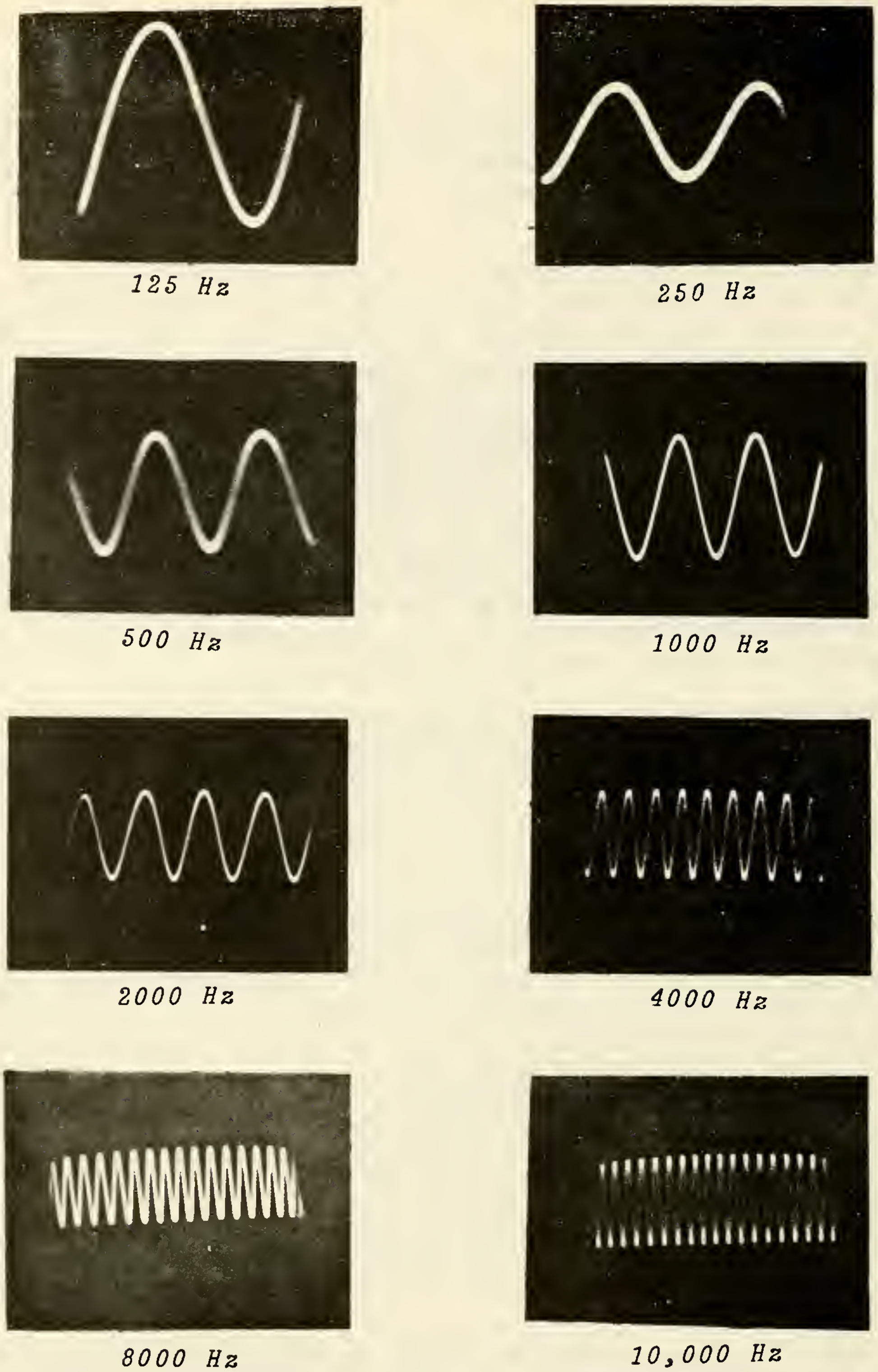

Figure 4. Oscillograms of the Stimulus Tones at the Position of the Headphones.

250 Hz 500 Hz

Figure 5. Oscillograms of Two of the Stimulus Tones After Being Transmitted Through the Headphones.

other tones were present; and

3. the wave forms of the stimulus tones that rode on the 60 Hz wave were altered in no other respect.

We believe that we were justified, therefore, in assuming that our stimulus sounds were pure tones.

Procedure

Beginning with the lowest tone and progressing to the highest, an experimental series was conducted with each of these stimulus tones. The intensity of the tone, which was adjusted by the attenuator, was, with two exceptions, the same as that chosen by *S* for the thermal noise.[3]

S's instructions were the same as in Experiment 1. After a few practice trials every *S* was given 40 trials, 10 from each of the starting points previously used, with every stimulus tone. As before, the circuit to *S*'s station in the soundproof room was cut between successive trials while *E* returned the stimulus carriage to the next starting point. *S*'s reports were given *E* over the telephonic communicating system immediately after every trial. The masonite screen, again used as the obstacle, was placed haphazardly at 6 or 12 ft in front of the end wall.

Results

Although the instructions were the same as in Experiment 1 and in

the previous studies, none of the *S*s stopped the approaching stimulus tone more than once during the course of a single trial. Their 'first perceptions' were their 'final appraisals.' The *S*s were unwilling, once they had stopped the approaching tone, to attempt to bring it closer to the obstacle for fear of a collision.

The results of this experiment are given in Table III, which shows the number of times in 40 trials, with every stimulus tone, the carriage was stopped before it struck the obstacle, the average distance and stimulus distance (in feet) that it was stopped from the obstacle, and the number of collisions.

TABLE III

RESULTS OF EXPERIMENT 3

The Number of Times Out of 40 Trials with Every Stimulus Tone That the *S*s Stopped the Moving Carriage before It Collided with the Obstacle, the Average Distance and Stimulus Distance (in Ft) of Those Stops from the Obstacles, and the Number of Collisions.

S		Stimulus-tone							
		125∼	250⌒	500∼	1000∼	2000∼	4000⌒	8000⌒	10,000⌒
FB	No. stops	7	7	3	0	8	31	17	40
	Av. distance	2.57	0.29	0.16	—	2.12	1.35	3.24	2.30
	SD	3.23	0.19	0.04	—	1.45	0.48	2.36	0.72
	No. collisions	33	33	37	40	32	9	23	0
SB	No. stops	33	0	4	0	21	11	9	40
	Av. distance	6.64	—	3.75	—	2.24	2.64	2.83	2.25
	SD	5.80	—	0.96	—	1.30	2.11	2.26	0.45
	No. collisions	7	40	36	40	19	29	31	0
CS	No. stops	21	14	5	0	22	0	4	39
	Av. distance	2.21	1.36	3.23	—	3.00	—	3.13	1.53
	SD	2.20	1.48	3.31	—	1.83	—	2.25	0.40
	No. collisions	19	26	35	40	18	40	36	1
MS	No. stops	18	15	21	15	34	10	4	37
	Av. distance	3.75	4.23	4.52	4.20	6.56	4.40	7.50	0.86
	SD	3.36	5.36	2.70	3.67	4.40	1.96	3.11	0.17
	No. collisions	22	25	19	25	6	30	36	3
	Total stops	79	36	33	15	85	52	34	156
	Total collisions	81	124	127	145	75	108	126	4

With Stimulus Tones of 8000 Hz and Less

Collisions were numerous during the trials when stimulus tones of 8000 Hz and less were used. Of the 280 trials with every *S* in these seven series, 207 (74 percent) resulted in collisions for *FB*, 202 (72 percent) for *SB*, 214 (76 percent) for *CS*, and 183 (65 percent) for *MS*. No improvement, moreover, was made in eliminating collisions during the course of these trials. Indeed, three of our four *S*s made more collisions in the seventh series than in the first and the change in the results of the fourth *S* was not great. Of the 160 trials made with every series by the four *S*s, 81 (50 percent) resulted in collisions in the first series and 126 (79 percent) in the seventh series.

The average distances of the 'stops' from the obstacle varied considerably from series to series and from trial to trial within a given series. There seemed to be no central tendency nor point about which the 'stops' clustered. The stimulus distances of the averages were at times larger than the averages. For series with 5 or more 'stops' per *S* (19 of the 28 series), the stimulus distances were greater than the averages in 4 instances, approximately equal to the average in 2, between 75 to 90 percent of the averages in 5, between 50 to 74 percent in 6, and less than 50 percent in 2. As indicated by the size of the stimulus distances, one 'stop' may be close to the obstacle and the next far from it. These results are similar to those obtained with deaf-blind *S*s - the 'stops' have little relation to their distance from the obstacle (see Worchel and Dallenbach, pp. 72-77, 88-91, and 103). They are much more closely related to the distance of the starting point from the obstacle than to the obstacle. When the starting point was far from the obstacle (24 ft), collisions were comparatively few in number and the distances of the 'stops' from the obstacle were large. Contrariwise, when the starting point was near the obstacle (6 ft), collisions were numerous and, in the instances in which collisions did not occur, the 'stops' (as necessarily would be the case if the stimulus carriage was moved forward) were close to the obstacle. The ranges of the 'stops' in series yielding the largest number were as follows: *FB*, 1/2 to 17 ft in the 4000 Hz series with 31 stops; *SB*, 1 to 18 ft in the 125 Hz series with 33 stops; *CS*, 1 to 16-1/2 ft in the 2000 Hz series with 22 stops; and *MS*, 1 to 16 ft in the 2000 Hz series with 34 stops.

There is little uniformity among the results of our *S*s, with stimulus tones of 8000 Hz and less, in the tones yielding the most stops and the most collisions. *FB* made the most stops with 4000 Hz, *SB* with 125 Hz, and *CS* and *MS* with 2000 Hz. Though three of our *S*s (*FB*, *SB*, *CS*) collided in every trial with 1000 Hz, *SB* did the same with 250 Hz and *CS* with 4000 Hz. *FB* had 37 collisions at 500 Hz, *CS* and *MS* had 36 at 8000 Hz, and *CS* 35 at 500 Hz. With

the exception of the results with the 1000 Hz stimulus tone, the uniformity of the 'failures' is as slight as that of the 'successes.'

We have no explanation as to why 1000 Hz should have yielded so many 'failures.' The *S*s, as we shall see, reported unusual difficulty with this tone. It offered, as they stated, no criteria upon which to base a judgment but their reports may have been merely reflections on their knowledge of their frequent failures because the *S*s always knew, from the resulting bump, when the carriage collided with the obstacle.

These results indicate, as we believe, that the performance of our *S*s, thus far considered, were dictated by chance factors and that frequencies of 8000 Hz and less are not adequate to the perception of the obstacles.

These conclusions are confirmed by the reports of the *S*s, examples of which appear below for every stimulus tone, that were given both between and after the successive trials.

Tone 125 Hz:

FB

"There are fluctuations in loudness but not very pronounced. They are irregular and undependable. I cannot make judgment with this tone" (33 stops, 7 collisions).

SB

"I notice intensive differences but on long series" (starting point at 18 and 24 ft). "I hear the differences twice. The tone gets louder, than softer, and then louder again - very deceptive. Some trials are easy to judge, others difficult because no changes are observed" (33 stops, 7 collisions).

CS

"The tone gets louder in three places in the long series. I cannot tell these places apart and sometimes the carriage hits the wall without the tone undergoing any changes. I can't do it with this tone" (21 stops, 19 collisions).

MS

"I wait for a change in the loudness - sometimes it comes and sometimes not. When it comes, it comes

suddenly. Most of the time there is no change at all" (18 stops, 22 collisions).

Tone 250 Hz:

FB

"I was guessing those times when it didn't hit. I could have run it farther as well as have stopped it where I did" (7 stops, 33 collisions).

SB

"I think the tone becomes louder when it nears the obstacle, but I am not certain" (40 collisions).

CS

"I don't know what I'm doing. I'm trying to learn an intensive pattern which apparently has nothing to do with nearness to the obstacle" (14 stops, 26 collisions).

MS

"There is a waxing and waning in intensity. I am trying to detect the wall by an intensive change. I cannot even guess how far the tone is from the wall - I do not believe I am making any correct judgments" (15 stops, 25 collisions).

Tone 500 Hz:

FB

"Once in a while I think I detect a change but it occurs so suddenly and so late that I cannot do anything about it" (3 stops, 37 collisions).

SB

"Same as the previous tone. No changes unless there is a slight increase in intensity just as it hits" (4 stops, 36 collisions).

CS

"Tone seems to vary intensively. I get no cue of the obstacle at all; no significant pattern change" (5 stops, 35 collisions).

MS

"I get the same change soon after I start the tone to move as I do just before it hits. I'm just guessing a a lot of the time I stop the carriage" (21 stops, 19 collisions).

Tone 1000 Hz:

FB

"I cannot do it at all with this tone. No changes upon which to base a judgment" (40 collisions).

SB

"The tone seems to get louder but the change is so gradual that I do not know where to stop it" (40 collisions).

CS

"I am not getting it at all with this tone. Nothing upon which I can base a judgment" (40 collisions).

MS

"I think there is a rise in pitch as the tone nears the obstacle" (15 stops, 25 collisions).

Tone 2000 Hz:

FB

"I am reacting to some kind of change but I don't know what it is and I don't know if I am right or wrong" (8 stops, 32 collisions).

SB

"I'm getting something now. I can hear differences from time to time. The changes are gradual" (21 stops, 19 collisions).

CS

"I'd say the tone increased in loudness at certain points, but I am guessing" (22 stops, 18 collisions).

MS

"I think there is a slight and gradual change in

pitch but I need a long and rapid run to get it. That is why I cannot bring the tone to a 'near' approach. I am stopping the carriage where a rise in pitch begins but it may be imaginary" (34 stops, 6 collisions).

Tone 4000 Hz:

FB

"I hear beats," (*S*, a piano tuner, was highly trained in the perception of beats), "which become more rapid up close to the obstacle. When the carriage is started from a short distance I cannot judge its approach because the beats are in their last phase and there is nothing with which to compare them. When started from a far distance the beats are slow. When they become rapid, like a chirping sound, I assume the obstacle is there" (31 stops, 9 collisions).

SB

"The tone fluctuates so much that I cannot tell a thing about it" (11 stops, 29 collisions).

CS

"There may be a gradual increase in loudness but I cannot detect a point of change. Nothing present upon which base a judgment" (40 collisions).

MS

"If there is a change in the tone, it is too gradual to tell when it occurs" (10 stops, 30 collisions).

Tone 8000 Hz:

FB

"Get beats all the time. When the obstacle is near they become very rapid" (9 stops, 31 collisions).

SB

"Tone fluctuates irregularly. When I make a judgment it is a guess based on a change in volume" (17 stops, 23 collisions).

CS

"The tone fluctuates as it moves but it does not make any change that is invariably related to the obstacle. The stops I made were guesses" (4 stops, 36 collisions).

MS

"I haven't a criterion and I cannot find one. The stops I made were guesses" (4 stops, 36 collisions).

As these reports show, the *S*s sought a criterion upon which they could base their judgments. They tried to locate the obstacle in terms of various dimensional and phenomenal changes (loudness, pitch, volume, beats, and other fluctuations) which they thought occurred at times in the advancing tone. When these attempts with stimulus tones of 8000 Hz and less failed to yield an invariable indicator of the presence of the obstacle, they readily admitted that they could find no criterion and that they were guessing when they stopped the carriage. From the reports of the *S*s alone, even without the corroborative evidence of their performance, we would be justified in concluding that frequencies of 8000 Hz and less do not supply a criterion that is adequate to the perception of obstacles.

With Stimulus Tones of 10,000 Hz

When we turn to the results with the stimulus tone of 10,000 Hz, the picture immediately changes. Of the 40 trials with this tone, *FB* and *SB* were successful in all, *CS* in 39, and *MS* in 37. *CS*'s and *MS*'s collisions, 1 and 3 respectively, were due, unlike those with the other stimulus tones, to delayed reactions in stopping the stimulus carriage. They occurred, as the *S*s reported, shortly after the obstacle had been perceived.[4]

The *S*s stopped the advancing tone when they perceived a change in it. They again made but one judgment during a trial as they were unable, and unwilling to attempt, to bring the tone closer than their first stop since such attempts always resulted in collisions. The distances of the 'stops' from the obstacle, the averages of which varied from 0.86 ft for *MS* to 2.3 ft for *FB*, were not sufficient for *S* to start the tone moving, to listen attentively to it, and to stop it before the bumper of the carriage struck the obstacle.

The average distance of the 'stops' with the 10,000 Hz tone were, moreover, much more constant than with tones of lower frequencies. The stimulus distances were 31 percent of *FB*'s average, 25 percent of *SB*'s, 26 percent of *CS*'s, and 20 percent of *MS*'s. As the stimulus distances indicate, the 'stops' were related to the

obstacle. In not a single instance was a 'stop' made at a great distance from the screen. The ranges of the stops were as follows: *FB*, 1 to 4 ft; *SB*, 1/2 to 3 ft; *CS*, 1 to 2 ft; and *MS*, 1/2 to 1-1/2 ft.

In the percentage of success and consistency of performance, as that is represented by the stimulus distance and range, the results of the *S*s with the 10,000 Hz tone resemble those in Experiment 1 with the thermal noise and in the Preliminary Training Series in which *E* walked toward the obstacle. We believe we are justified, therefore, in concluding

1. that our *S*s perceived the obstacle with this stimulus tone,

2. that high frequencies of approximately 10,000 Hz and above are necessary conditions for the perception, and

3. that a high tone of a single frequency is a sufficient condition for it.

These conclusions are corroborated by the reports of the *S*s, samples of which follow.

Tone 10,000 Hz:

FB

"With this tone there are fluctuations like ripples on the water. When it nears the obstacle, I know something is there. The change is very noticeable. The fluctuations get so rapid when close to the obstacle that they are like a buzzing sound" (40 stops).

SB

"The tone becomes more piercing and shrill when it nears the obstacle. The change is obvious. I can perceive the obstacle with this tone" (40 stops).

CS

"The tone suddenly gets louder...it screams when near the obstacle. The change may be a rise in pitch. This is easy to do" (39 stops, 1 collision).

MS

"This is easy. Next to the thermal noise this is

the easiest of all. There is a sudden change, in loudness and pitch I believe, when it nears the obstacle" (37 stops, 3 collisions).

All the *S*s were confident of their ability to perceive the obstacle with the 10,000 Hz tone. They were in agreement in that respect, but they were not in agreement regarding the phenomenal cue that served them as the basis of the perception. *FB*'s criterion was a change in the rate of fluctuation. He said that the change was "very noticeable" but he could not say definitely whether the fluctuations were in pitch or in loudness. *SB* believed the cue was a change in pitch. When the pitch rose - that is, suddenly became "shrill" - he reported the presence of the obstacle. *CS* reported the obstacle when the tone suddenly became "louder" but she was uncertain as she also stated that "the change may be a rise in pitch." *MS* thought the change, which was sudden, was in both loudness and pitch.

Besides confirming the conclusions drawn above, the reports of the *S*s set the stage for the next experiment.

Experiment 4

The problem of Experiment 4 was to determine whether loudness was involved in the preception of obstacles. The question we sought specifically to answer was: Does a constant sound stimulus change in loudness with its distance from an obstacle? If the change is in loudness, then a stimulus close to the obstacle should be louder than one farther away.

Method

The thermal noise of Experiment 1 was used as the stimulus sound. It was selected because its intensity was constant and because the *S*s perceived the obstacle very easily with it. This stimulus was transmitted to *S* in the soundproof room as before - that is, from the loudspeaker to the obstacle, to the microphone, through the amplifier and attenuator, and on to *S*'s headphones.

The end wall of the hall was the obstacle in this series of experiments. It was selected because *S*'s perceptions were better with it than with the masonite screen and also because the reasons for using the screen were no longer cogent.[5]

The loudspeaker was placed at 7 distances - 0, 1, 2, 3, 4, 5, and 6 ft - from the wall. (As these distances were measured from the wall to the tip of the bumper, a constant of 2 in. must be added to each of them, since the bumper projected that distance in front of the forward line of the loudspeaker and microphone.) We used 6 ft as the maximal distance because 5.4 ft was the largest average distance (see Table II) at which the obstacle was perceived by any of our *S*s; and 0 ft because presumably the loudness would be

greatest there. Our range of stimulus distances should cover the maximal variations in loudness. The intensive limens were measured for every *S* in dB reductions from a common setting of the attenuator at each of these distances. The continuous method of limits was employed.

Subjects

In addition to the other *S*s, *DS*, the senior author, served in this experiment. The following instructions were given *S* before every experimental period.

> "After a signal - the sound of an electrical buzzer - you will hear a thermal noise. It will gradually diminish in loudness. As soon as it disappears, push your signal button" (which rang the bell on *E*'s desk). "This constitutes a descending series. After a short interval the buzzer will sound again and the noise will again be sounded but at an inaudible intensity. It will, however, be increased gradually. Signal as soon as you hear it. This is an ascending series. You will be told before every series whether it will be descending or ascending."

Procedure

Between successive series, *S* was given a short rest. During these periods the output plug of the attenuator was removed so that he would not hear what was being done in the experimental room.

1. Twenty series (10 descending and 10 ascending) were conducted at every stimulus distance. Half of these were conducted for three *S*s (*SB*, *CS*, and *DS*) with the loudspeaker at 0, then at 1, 2, 3, 4, 5, and 6 ft, at which point the second half were conducted in reverse order. For the other *S*s (*FB* and *MS*) this sequence was inverted; they began at 6 ft, worked toward 0 and then back again to 6 ft. We hoped by this procedure to cancel effects of practice and fatigue.

Our procedure did not, however, accomplish this. We found that regardless of the distance at which we started the determinations - that is, 0 or 6 ft - the limens at first decreased and then gradually increased, and that there was, moreover, a greater difference between the limens obtained at the first and last series than between those at the intermediate series. For example, *CS*'s liminal determinations started and ended at 0 ft. Her first and fourteenth series of 10 trials each were made at that distance and her sixth and seventh series (intermediate) were made at 6 ft. Her limens computed from the two series of 10 trials at

0 ft differed by 11.6 dB, whereas they differed at 6 ft only by 2.3 dB. Again, *MS*, with whom the procedure was reversed, made his first and last series of determinations at 6 ft and his intermediate series at 0 ft. His limens at 0 ft differed by 1.2 dB, whereas at 6 ft they differed by 13.9 dB.

The time order of the determinations had greater effect upon the limens than the stimulus distances. Indeed, if stimulus distance had any effect upon *S*'s intensive judgments in these trials, it was hidden by the effects of practice, fatigue, and ennui.

2. To reduce the effects of fatigue and ennui, we decreased the number of stimulus distances at which we determined intensive limens to three; namely, 0, 3, and 6 ft. We ran 40 series by the continuous method of limits at each distance for every *S*, counterbalancing order and stimulus distance. Again we found that the limens varied, regardless of the stimulus distance, with the order in which they were determined. There were, for all the *S*s, greater differences between the limens determined by the first and last groups of series, whether made at 0 or 6 ft, than between the two middle groups, whether made at 6 or 0 ft.

3. Since we were primarily concerned with discovering whether there was any difference in the loudness of the thermal noise at the 'first perception' and the 'final appraisal,' we reduced the number of stimulus distances at which limens were determined to two; namely, 0 and 6 ft. If differences in loudness existed, they should be maximal at these distances.

This procedure eliminated, as we thought, the effects of practice, fatigue and ennui: of practice, because by now every *S* had made several hundreds of intensive judgments; and of fatigue and ennui, because *S* had to make fewer judgments and the series lasted a much shorter time than in the previous procedures.

Intensive limens were again determined by the continuous method of limits in 4 groups of 10 series each, counterbalanced as to order and stimulus distance. Frequent rests were also given *S*.

Results

The results of the third procedure are given in Table IV. At last we had obtained conditions under which the time order of the determinations had no effect upon the limens. As Table IV shows, the limens at 0 ft from the wall were greater for all the *S*s, regardless of time order, than at 6 ft. The differences between these limens are, however, small. They vary from 0.15 dB for *DS* to 0.90 dB for *CS*. The critical ratios of the differences are also small - varying from 0.34 for *DS* to 1.59 for *SB*. Indeed, the critical ratios are so small that we are forced to conclude that the differences are insignificant and are due to chance, not to differences

in the distance of the stimulus noises from the wall.

The fact that the differences though small lie in the same direction for all the *S*s might under other circumstances be regarded as significant. In the present case, however, the differences are fractions of a just noticeable difference, hence too small to be discriminated. Difference in loudness cannot, therefore, be the basis of our *S*s' perception of an obstacle.

TABLE IV

RESULTS OF PROCEDURE 3 OF EXPERIMENT 4

Limens in dB At Each Stimulus Distance, Difference between the Limens, and the Critical Ratios of these Differences.

S	Stimulus-distance (in ft.)	Limen (in db.)	*SD*	Diff.	*CR*
FB	0	63.0	3.01		
	6	62.5	3.08	0.50	0.73
SB	0	61.1	1.98		
	6	60.3	2.48	0.80	1.59
CS	0	51.0	2.66		
	6	50.1	2.51	0.90	1.56
MS	0	52.2	3.73		
	6	51.6	2.98	0.60	0.80
DS	0	49.2	2.12		
	6	49.0	1.74	0.15	0.34

To test this conclusion, we asked the *S*s, in a short supplementary experiment, to compare the loudness of two successively presented stimuli. The apparatus and procedure were the same as described above with the following exceptions. The intensity of the stimulus was held constant and successive presentations were made at the following positions in front of the wall: 0 ft to 0 ft; 0 ft to 6 ft; 6 ft to 0 ft; and 6 ft to 6 ft. Both the constancy of the stimulus and the positions at which it was presented were unknown to *S*. *S* had merely to report whether the loudness of the stimuli was the 'same' or 'different.' The reports of all the *S*s were 'same' throughout, whether presented successively at the same or different distances from the wall.

From the results of Experiment 4, we believe that we are justified in concluding that changes in loudness are neither a *necessary* nor a *sufficient* condition for the perception of obstacles.

SUMMARY OF RESULTS

As we have seen this study, our *S*s (blind and blindfold-sighted alike) were highly successful (preliminary training series) in perceiving an obstacle when they themselves walked toward it under conditions in which they heard the sounds of their footsteps. When hearing was eliminated they failed, as did the *S*s in the studies reported earlier from this laboratory. They were again successful, however, when they listened from a soundproof room to the sounds of *E*'s footsteps as he approached an obstacle though they were handicapped by their inability to control *E*'s rate of walking and intensity of tread.

Our *S*s were also successful (Experiment 1 of this study) when a continuous sound - a thermal noise, containing all the audible frequencies at a high level of intensity, whose rate of approach they controlled - was used as the stimulus. They reported 'first perceptions' and 'final appraisals' and the ratios of the average distances of these reports were superior to the ratios obtained for the same *S*s with intermittent sounds heard under comparable conditions - for example, *E*'s footsteps heard by *S* from the soundproof room. Our *S*s also reported that their judgments were based upon changes in pitch, which rose suddenly and continued to rise until the stimulus was close to the obstacle. The beginning and end of the rise marked, respectively, the 'first perception' and the 'final appraisal.'

The successes of our *S*s with the continuous sound were due (Experiment 2) to changes inherent in the approaching stimulus and not to extraneous changes introduced by the apparatus - for example, the moving carriage.

None of our *S*s (Experiment 3) was able to perceive obstacles when the continuous stimulus was reduced to single frequencies - that is, to pure tones, varying by the octave relationship from 125 Hz to 8000 Hz. Although all the *S*s stopped the moving stimulus tone at times, their judgments were "guesses," as they reported, or were dictated by cues eventually discovered to be false. They were unable with single frequencies of 8000 Hz or less to find reliable cues upon which to base their judgments.

When, however, the frequency of the stimulus tone was raised to 10,000 Hz, all of our *S*s were successful. They were again able to perceive the obstacle. They were not able, however, to judge or to distinguish between 'first perceptions' and 'final appraisals' which they could do under conditions of their previous suc-

cesses. Their 'stops' were, moreover, inferior as measured by distance from the obstacle, to the 'first perceptions' reported under other conditions. Though confident in their ability to detect obstacles with this tone and successful in their performance, the *S*s were uncertain whether the cue upon which their judgments were based was a change in pitch or loudness or both.

Our *S*s' stimulus limens (Experiment 4) were the same whether determined at 0 or 6 ft from the wall, the critical distances in the perception of obstacles. The loudness of the sound was not affected by its nearness or remoteness to the obstacle. The *S*s, moreover, were not able to differentiate between the loudness of the thermal noise (the most adequate stimulus for the perception of obstacles that we used) when placed at 0 and at 6 ft before the wall, or to judge, upon the basis of loudness, whether the stimulus was at one or the other of these two positions.

DISCUSSIONS AND CONCLUSIONS

It is evident from the results of Experiment 4, which we shall first consider, that loudness of the stimulus sounds does not play a role in the perception of obstacles. Now that this has been demonstrated, it is apparent; and it could have been predicted because the loudness of a constant stimulus sound varies, not with *S*'s (or, in our experiments, with the carriage's) distance from an obstacle, but with the distance between *S*'s footfalls and his ears (or the loudspeaker and the microphone). Since the distance between *S*'s ears and footfalls (or microphone and loudspeaker) is constant during *S*'s (or the carriage's) approach, the loudness of the stimulus sound will remain constant. This would be true even though the soundwaves reflected from the obstacle came to *S*'s ears (or the microphone) with increased intensity as *S* (or the carriage) neared the obstacle, because the slight increase would be concealed or masked by the greater intensity of the soundwaves traveling directly from footfall to ear (or loudspeaker to microphone). The *S*s' indecision in Experiment 3, regarding the character of the change when the 10,000 Hz tone was used as the stimulus (that is, whether the change, which served as the criterion of their judgments, was in pitch, loudness or both) was doubtlessly due to their lack of familiarity with pitch changes in pure tones of high frequency.

It is also evident, from the results of Experiments 1 and 3, that changes in pitch are the basic cues of the perception of obstacles by the blind, and that they do not occur unles the higher partials, approximately 10,000 Hz and above, are present in the stimulus sounds.

The conclusion that pitch changes are the basic cues derives from the reports of the *S*s throughout the study but in particular

in Experiment 1 with the thermal noise. That the *S* should be able to state that the changes in the thermal noise were definitely 'pitch' and not be able to be as definite when the 10,000 Hz tone was used, is due to the greater complexity of the wave pattern of the thermal noise, and, as suggested above, to the *S*s' unfamiliarity with pitch changes in pure tones of high frequencies.

The thermal noise contains all audible frequencies at a high level of intensity and each and every frequency contributes its measure to the perceptual change. Indeed, this stimulus sound was selected for that very reason.[2] Conditions were maximal for *S*'s observations as well as for his performances. When the 10,000 Hz tone was used, we had one frequency which was at or only slightly above the limit necessary for the perception of obstacles. Conditions for observation and performance were minimal. It is not surprising, therefore, that the *S*s were less definite in their reports when this tone was the stimulus.

The conclusion that changes in pitch are dependent upon high audible frequencies of approximately 10,000 Hz and above is based upon the fact that our *S*s were successful in perceiving the obstacle only when stimuli (footsteps, thermal noise, the 10,000 Hz tone) containing frequencies within that range were used. With stimulus tones of 125 to 8000 Hz, they failed.

The rise in pitch, observable only when stimuli containing high frequencies are used, is due, as we believe, to the Doppler effect. We hazard this explanation for the following reasons.

1. The descriptions of the changes in the stimulus sound are like those of the Doppler effect. For example, our *S*s described the changes upon which they based their judgments in Experiment 1 as follows:

> *FB*
>
> "A change in pitch that rises continuously up to the obstacle."
>
> *SB*
>
> "The sound rises in pitch up to the obstacle....All I have to do is to listen to the first and last change."
>
> *CS*
>
> "The pitch becomes higher when the obstacle 'comes in' and continues to rise until it gets very close to it."

MS

"My 'first perception' is the beginning of the siren effect; for my 'final appraisal' I try to stop the movement when the sound is at its highest."

2. Though the rate of movement of the stimulus sounds in our experiments is not rapid enough to produce the Doppler effect by itself, it may be sufficient in conjunction with the movement of the receiver (*S* or microphone).

Since the soundsource (*S*'s footsteps or the loudspeaker) and the receiver (*S*'s ears or the microphone) are both moving together toward a stationary obstacle, a two-fold shift in frequency occurs: one at the obstacle in the sounds emitted by the sound source (*S*'s footsteps or the loudspeaker); and the other at the receiver (*S*'s ears or microphone) in the sounds reflected from the obstacle. Because of this two-fold increase, rates of movement that are themselves too slow to show the Doppler effect may be brought within its range.

The maximal rate of movement of the carriage to which the loudspeaker (the sound source) and the microphone (receiver) were attached, was set, in our experiments, at 4 ft/sec. The *S*s, however, rarely moved it at this speed. They usually moved it, particularly at critical points, at speeds which were estimated to be between 2 to 3 ft/sec.

The Doppler shift, with the thermal noise as the stimulus, is 53 Hz with speeds of 2 ft/sec, and 80 Hz with speeds of 3 ft/sec, as computed by the formula:

$$\Delta_v = v(v_s + v_r) \checkmark (V - v_s)$$

in which Δ_v is the amount of the Doppler shift, v the transmitting frequency, v_s the velocity of the source, v_r the velocity of the receiver, and V the velocity of the sound (12). In the computation of these values of the Doppler effect, the frequency of the thermal noise was taken to be the average of the audible frequencies above 10,000 Hz (the frequency we found to be adequate to the perception of obstacles) - that is, 15,000 Hz, the average of the frequencies between 10,000 to 20,000 Hz.

At carriage speeds of 3 ft/sec, which the *S*s used most frequently when pure tones were the stimulus sounds, the frequency shift in the stimulus tones is 53 Hz at 10,000 Hz, 42 at 8000, 21 at 4000, 10 at 2000, 5.3 at 1000, 2.6 at 500, 1.3 at 250, and 0.67 Hz at 125 Hz. The shift with the 10,000 Hz tone is the only one, under our conditions, that is large enough to produce the Doppler effect.

These results explain, as we believe, why our *S*s were unable to find a criterion when stimulus tones of 8000 Hz and less were used; and also why, once they had stopped the approaching stimulus in trials with the 10,000 Hz tone, they did not start it again for the 'near' approach and 'final appraisal.' Fear of a collision was the reason the *S*s gave, but the real reason is, as we believe, the distance of the 'stops' from the obstacle - averaging 0.86 ft for *MS*, 1.53 ft for *CS*, 2.25 ft for *SB*, and 2.30 for *FB*. These distances are so short that velocities cannot be reached within the available space and time, when the carriage is started again, that would yield liminal shifts in the frequency of the stimulus tone. Under those conditions, pitch changes would not be noted, judgments made, nor collisions avoided. Unless frequencies and velocities are available in the stimulus conditions that produce changes in pitch *S* will not be able, because of a lack of this criterion, to perceive the obstacle.

Had our *S*s utilized the maximal velocity available to them (4 ft/sec) or had we increased the permissible rate from a normal walk to a run (20 ft/sec) they doubtlessly would have perceived obstacles with lower stimulus frequencies, but in that case the moving carriage would probably be upon the obstacle before they could render a judgment and stop it. The relation of wavelength and velocity of movement to distance at which obstacles are perceived still remains an unsolved problem.

The conclusions of this study may be briefly summarized. They are:

1. Changes in pitch are both a necessary and a sufficient condition for the perception of obstacles by the blind.

2. Changes in loudness are neither a necessary nor a sufficient condition for the perception.

3. Under like conditions, continuous sounds are as adequate to the perception as intermittent sounds.

4. At speeds of normal walking, high frequencies of approximately 10,000 Hz and above are necessary conditions; frequencies of approximately 8000 Hz and below are insufficient conditions.

5. A high tone of a single frequency is a sufficient condition.

6. The pitch changes - that is, the fundamental basis of the perception of obstacles by the blind - are results of the Doppler shift.

FOOTNOTES

1. We are indebted to Drs. E. H. Cowell and F. R. C. Forster of Ithaca, New York, for these examinations and reports. Dr. Cowell examined *SB*'s eyes, and Dr. Forster, *FB*'s.

2. We also began with this experiment because we wished at the beginning of the study to give the *S*s maximal opportunity to detect the obstacle. If pitch did play a part in the perception, it would, as we believed, be advantageous to begin with a complex sound that contained all the audible pitches at high intensity. If by chance we began the study with a pure tone whose pitch played no role in the perception and the *S*s failed, they might become discouraged and conditioned by their failures and their performances in subsequent series be adversely affected.

3. We found it impossible, within the limitations of our apparatus, to raise the intensity of the stimulus tones of 8000 Hz and 10,000 Hz to the intensity level selected by *FB* (66 dB). His audiogram shows 10 percent losses at both of these frequencies for his better ear and 25 percent and 20 percent losses, respectively, for his poorer ear. We, therefore, set the attenuator, when these tones were used with him, at its maximal level, which was about 35 dB above his limens for them.

4. Though the instructions still called for reports of 'first perceptions' and 'final appraisals' none of our *S*s reported them. As with the other tones, they stopped the advancing stimulus but once during a single trial. This may have been due to habits established during the first seven series of this experiment, or to the fact that the 10,000 Hz tone was borderline - at or near the frequency limen required for the detection of obstacles - and the differential judgments requested in the instructions were consequently extremely difficult or impossible - as judgments near the limen are apt to be. Besides reading the instructions to the *S*s at the beginning of every experimental hour, we did not press them, after they had stopped the approaching tone, to bring it as close as possible to the obstacle. We were afraid, now that the *S*s were on the point of discovering reliable cues upon which their judgments could be based, to add to the complexity of their task. Failure with 10,000 Hz, since we were unable (due to limitations of our apparatus) to present stimulus tones of higher frequencies, would mean the failure of this investigation - at least as far as positive evidence is concerned. Now was not the time, therefore, to add complications to *S*'s task.

5. The rise in pitch when the moving sound came within 6 ft of the wall was not due, as we thought might be possible, to vibrations of the suspension wires but was, as we discovered in Experiment 3, inherent in the approaching sound.

"FACIAL VISION": THE PERCEPTION OF OBSTACLES OUT OF DOORS BY BLINDFOLDED AND BLINDFOLDED-DEAFENED SUBJECTS*

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INTRODUCTION

In the Cornell series of studies upon the perception and avoidance of obstacles without vision, it was found (1) that audition is the necessary and sufficient condition; (2) that pitch is the auditory dimension involved in the perception; and (3) that high audible frequencies of approximately 10,000 Hz and above are necessary stimulus conditions (see pp. 1-152). In the light of these results, anyone, blind or blindfolded alike, possessing normal hearing should be able to acquire the ability.

These conclusions, particularly those bearing upon the normalcy of the perception, stand in opposition to the findings of the earlier investigators. Many of the earlier writers regard "facial vision" as a special ability, like artistic, mathematical, or musical talent, which is not shared by everyone (15, 16). Diderot, the first to investigate this problem, regarded obstacle perception as an "amazing ability" possessed only by a few of the blind (3). This point of view has found support in the fact that not every blind person possesses the ability nor is able to acquire it. Villey, for example, found that only 42 (66.6 percent) of 63 soldiers blinded in World War I had been able to acquire the ability during the dozen or more years since their injuries (39). Wolfflin found large individual differences among his *S*s: some possessed a "fine obstacle sense," some had only a "weak sense," and some lacked it entirely (42). Lamarque similarly found wide

* Reprinted from The American Journal of Psychology, Vol. 66, No. 4 (October 1953), pp. 519-553. This study, the experiments of which were conducted at Tulane University by the junior authors during the fall of 1947 and winter of 1948, was suggested by the senior author who is responsible also for the present report.

variations among his *S*s (25). The superiority in performance of blind over blindfolded sighted *S*s, repeatedly demonstrated in experiments, has also been regarded as evidence of a special ability which reaches its highest development only in the blind (22).

PROBLEM

The purpose of the present study was twofold: (1) to determine whether the results and conclusions of the Cornell studies - which were conducted indoors in a large enclosed hall - could be duplicated when the experiments were conducted outdoors under conditions approximating more nearly those met by the blind in everyday life; and (2) to discover whether every person with normal hearing - blind and blindfolded alike - is able to acquire the ability to perceive obstacles - a consequence of the conclusion that *audition is the necessary and sufficient condition.*

METHOD AND PROCEDURE

This study was divided into two parts (Parts I and II) of four and three series of experiments, respectively. All the experiments were conducted out of doors on a 4-ft wide concrete walk which extended from the side door of the Psychological Laboratory of Tulane University across the campus quadrangle at an angle of about 11 degrees. The experimental area was 60 ft in length. The first 40 ft were bounded on one side by the Laboratory, but the last 20 ft were in the clear - that is, no building was on either side or in front of it nearer than 200 ft. Grass bordered both sides of the walk.

A heavily traveled boulevard was about 300 ft from the experimental area. To people with normal hearing, the traffic noises were clearly audible, as were the noises from adjacent construction - pneumatic hammers and drills, and the like - and from students going to and fro between classes. Passersby were blocked from the experimental walk, but they were permitted to go around it on the grass. The noise level at the experimental area, which was measured frequently by a General Radio Sound-Level Meter, Type 759 during the experimental periods, varied from 30 to 70 dB, being at the higher levels most of the time.

The procedure throughout all the experiments was the same as that used in the Cornell studies (see Supa, Cotzin, and Dallenbach, pp. 19 and 30). After being blindfolded, *S* was placed at one of five starting positions - 0, 3, 6, 9, or 12 ft from a fixed point near the laboratory door - and instructed to go down the walk toward an obstacle that was at one of five distances - 6, 12, 18, 24, or 30 ft - from the starting position. Both starting position and obstacle distance were selected by planned haphazard choice which guaranteed that each was used as frequently as every other one. None of the *S*s knew the obstacle distances used nor that he was

placed at different starting positions at successive trials. When brought to a starting point, *S*, at a tap on his back, walked towards the obstacle until he perceived it or collided with it. If he perceived it, he stopped, raised his right arm ('first perception') and then, at a second tap, continued to approach it, attempting to come as near as possible to it without touching it, when he again stopped and raised his left arm ('final appraisal').

Two *E*s were used throughout the trials, E_1 had charge of the obstacle, placing it at different positions according to the design of the experiment. E_2 had charge of *S*, placing him at the proper starting point, giving him the starting and continuing signals, recording the distances of his 'first perceptions' (p) and 'final appraisals' (a) from the obstacle, and leading him back after a trial to the next starting point. The return to the starting point was made in a circuitous route over the grass so that *S* would be disoriented and would not know how far he had walked during the trial. The *E*s interchanged duties on alternate days that no habitual, involuntary cues regarding the position of the obstacle would be given by them to the *S*s. If either gave the *S*s cues involuntarily, that should become evident in differences in the *S*s' performances on alternate days. (No constant difference was detected between the performances on alternate days hence the *E*s gave either similar involuntary cues or none. We believe they gave none.)

A series of 30 trials was completed by an *S* during an experimental hour. *S* served at the same hour every day except Sunday (which was omitted because the noises of the other days were either greatly reduced or entirely absent) and until he had completed 8 series of 30 trials each or had clearly demonstrated that he had learned to perceive obstacles - whichever came first.

Our criterion of learning was 25 successes in 30 trials, a success being scored when *S reported* his 'first perception' and 'final appraisal' without touching the obstacle. If he could not accomplish that criterion within 240 trials, it was assumed that he could not learn to perceive obstacles under the conditions under which he was serving, and that part or phase of the study was discontinued with him.

Subjects

The *S*s, 20 in number (7 women and 13 men), were students majoring in psychology at Tulane University. All were naive regarding 'obstacle perception' and the purpose of this study. When the immediate task was explained to them - that they were to learn to detect the presence of obstacles without vision - they all expressed grave doubts regarding their ability to do so but were willing to try.

The *S*s were divided by chance into two groups (Groups A and B). In Part I of the study, the *S*s of Group A were merely blindfolded, their hearing was left intact, whereas the *S*s of Group B, in addition to being blindfolded, had their hearing impaired by having their ears stopped. In Part II, these conditions were reversed. The *S*s of Group A were blindfolded and deafened and those of Group B were merely blindfolded.

Audiograms by air conduction were made with a Maico Audiometer for all the *S*s. The results are summarized for the *S*s of each group in Table I. As this table shows, 8 *S*s of Group A and 7 of Group B possess normal hearing in one or both ears[1] and 2 of

TABLE I

SUMMARY OF THE MAICO AUDIOGRAMS OF THE TWO GROUPS OF *S*s

Group A				Group B			
S	Age (yr.)	College standing	Maico audiogram	*S*	Age (yr.)	College standing	Maico audiogram
1. *AL*	19	Jr.	normal, both ears	1. *MB*	19	Soph.	normal, both ears
2. *CW*	22	Sr.	normal, both ears	2. *CF*	20	Gr.	normal, both ears
3. *NW*	19	Soph.	normal, both ears	3. *MS*	20	Sr.	normal, both ears
4. *SR*	23	Jr.	normal, both ears	4. *WW*	24	Gr.	normal, both ears
5. *DL*	20	Jr.	normal, both ears; superior lower ranges	5. *JB*	23	Sr.	normal right ear; 60-db. loss in left ear at 11,584~
6. *LA*	21	Sr.	normal, both ears; superior upper ranges	6. *JR*	24	Sr.	normal right ear; 20-db. loss left ear at 1024~ and above
7. *GS*	29	Sr.	normal left ear; 50-db. loss in right ear at all frequencies	7. *BJ*	21	Soph.	normal right ear; 60-db. loss left ear at 11,584~
8. *AM*	20	Gr.	normal left ear; 55-db. loss in right ear at all frequencies	8. *DE*	26	Sr.	right ear: normal except 40-db. loss at 4095~ and above; left ear: normal except 30-db. loss at 11,584~
9. *BH*	21	Sr.	normal both ears up to 8192~; 50-db. loss in both ears at 11,584~	9. *BG*	22	Jr.	normal both ears to 2896~; 25-db. loss in both ears at 4096~ and above
10. *JE*	21	Sr.	normal both ears up to 5792~; 20-db. loss in both ears at 8192~ and above	10. *ML*	23	Sr.	right ear: 10-db. loss at all frequencies to 8992~ and 40-bd. loss at 11,584~; left ear: normal below 512~ 30-db. loss between 1024~ and 8192~; and 60-db. loss at 11,584~

Group A and 3 of Group B have hearing losses in both ears of varying amounts at different frequency levels. For a chance division of the *S*s, the two groups are fairly well matched.

Apparatus

The obstacle placed in *S*'s path, a duplicate of the one used in all the Cornell experiments, was a 1/4-in. masonite board 4 ft wide and 4 ft 10 in. high. It was attached to a portable standard and so placed that its lower edge was 2 ft above the walk. Its upper edge (6 ft 10 in.) was therefore well above the height of *S*'s ears.

U. S. Navy Dark Adapter Goggles, cotton filled and equipped with an opaque shield, were used as the blindfolds. They were sealed around the edges to *S*'s face with adhesive tape so that they would be completely lightproof.

S's hearing was impaired by inserting an MSA Ear-Defender into the meatus of each ear (see footnote 10, p. 52). Over this was placed a plug of modeling clay which was fitted snugly into the concha. Two layers of cotton batting, one of sponge rubber, and a woolen earmuff filled with cotton were then laid over the ears and held tightly in place by the elastic bands of the blindfold.

Under these conditions, the hearing loss for our 20 *S*s averaged approximately 30 dB at 64 to 4096 Hz and 50 dB at 5792 to 11,584 Hz. Despite this loss the *S*s could intermittently hear the louder noises of the experimental area and the click and scrape of their shoes on the walk. They could also understand *E* when he raised his voice above the usual intensity of normal speech.[2]

The edges of the walk were marked in feet. E_2 was able therefore to note by immediate inspection the distance from the otstacle at which *S* gave his judgments. *S*'s 'first perceptions' were measured to the nearest foot and his 'final appraisals' to the nearest quarter-foot.

PART I

Experiment 1

The object of Experiment 1 was twofold: (1) to discover whether blindfolded *S*s, possessing normal or near-normal hearing, could learn to perceive obstacles out of doors; (2) to discover whether *S*s having their ears stopped in addition to being blindfolded could, out of doors, acquire the ability to perceive obstacles.

Procedure

The *S*s of the two groups (Groups A and B) served in chance order as their schedules permitted but always, for a given *S*, at the same hour every day.

Instructions

At the beginning of every experimental period the following instructions were read *S*.

> "After you have been blindfolded you will be placed on a concrete walk facing an obstacle. When you are tapped on the back, walk forward to the obstacle. You must stay on the walk; if you step off, return to it and continue forward. When you perceive the obstacle raise your right arm. At a second tap on the back, lower your arm and continue toward the obstacle. Approach it as closely as possible without touching it. When you have reached the point, raise your left arm."

After reading the instructions, no word was spoken until after the conclusion of the trial which was ended with *S*'s 'final appraisal' of, or collision with, the obstacle. *S* was frequently asked after a good performance to describe the bases of his judgments.

Incentives

Since this was an experiment in learning we utilized the following incentives which have been found to be of aid to *S*:

1. punishment - *S* was allowed to crash into the obstacle;

2. reward - *S*'s successes were highly praised;

3. withholding reward - when *S*'s 'final appraisal' was more than 3 ft from the obstacle, praise was omitted, hence he knew that he had done poorly;

4. knowledge of results - after every 'final appraisal' *S* was led to the obstacle, thus he knew the amount of his error after every trial;

5. avoidance of fatigue and ennui - the trials during an experimental hour were reduced to 30 and *S* was given frequent rests; and

6. knowledge of task incomplete - *S* was frequently informed, particularly during the later part of the experimental hour, of the number of trials still to be made.

These incentives were the same as those used in the second Cornell study in the learning experiments with deaf-blind *S*s (see Worchel and Dallenbach, pp. 72-73).

Results

General

The *S*s of both groups had difficulty at first in approaching the obstacle without the guidance of the edges of the walk. During the early stages of the study they frequently veered in their course and walked onto the grass but with practice this occurred less and less frequently until finally they were able to negotiate it.

Collisions with the obstacle were of three kinds:

1. pre-'first-perception' collisions - that is, collisions made before *S* had reported that he had perceived the obstacle;

2. post-'first-perception' collisions - that is, collisions made after he had reported his 'first perception' but before he had entered upon the phase of 'final appraisal'; and

3. 'final-appraisal' collisions - that is, collisions made during the 'final appraisal' while *S* was attempting to improve his record by "inching up" to the obstacle which he knew was close before him.

The *S*s attaining criterion frequently reported that their judgments were based upon "a change in the sound" of their footsteps and upon the "sudden appearance of a black curtain or shade" before them. These "dark shades" were experienced only during the 'near approaches' and were often, particularly during the early phases of the study, reported to be the basis of the 'final appraisals.'

In every other respect except these just mentioned, the behavior and performance of the *S*s of the two groups differed greatly.

Learning

As Table II shows, all the *S*s of Group A (blindfolded only) met our criterion within the trial limits (8 series of 30 trials each) of the experiment.

For example: one *S* (A_6) reached criterion in Series 1. He possessed, as Table I shows, normal hearing in both ears at the lower audible ranges and superior hearing in both ears at the higher audible ranges. Three *S*s (A_1, A_2, and A_5) reached criterion in Series 2; one (A_4) in Series 3; three (A_7, A_8, and A_{10}) in Se-

ries 5; one (A_9) in Series 7; and one (A_3) in Series 8. As will be recalled (see Table I), eight *S*s of this group possessed normal hearing in at least one ear and two had defective hearing in both ears at the higher audible ranges.

The results of Group B (deafened and blindfolded) present a very different picture. Four of this group were unable to meet our criterion of learning.

TABLE II

RESULTS OF EXPERIMENT 1

The Number of Series Required by the *S*s of Each Group to Reach Criterion, the Mean Distances and SD (in Ft) of the 'First Perceptions' and 'Final Appraisals,' the Ratios of These Distances, and the Number of Collisions in the Series in Which Criterion was Reached.

Group A (blindfolded only)									Group B (blindfolded and deafened)								
S	No. of series required for criterion	*p*		*a*		*p/a*	No. of collisions		*S*	No. of series required for criterion	*p*		*a*		*p/a*	No. of collisions
		M	*SD*	*M*	*SD*						*M*	*SD*	*M*	*SD*		
1	2	6.61	5.06	1.79	2.21	3.6	4		1	4	10.97	8.19	9.19	8.52	1.1	5
2	2	7.69	8.40	1.41	2.18	5.5	2		2	—	—	—	—	—	—	12*
3	8	1.88	1.34	.33	.38	5.7	5		3	—	—	—	—	—	—	24*
4	3	5.04	5.18	3.38	3.08	1.5	5		4	3	.43	.24	.32	.21	1.3	3
5	2	8.47	7.09	2.40	2.06	3.5	3		5	3	8.92	7.95	5.16	7.32	1.7	5
6	1	11.66	8.16	2.93	2.12	4.1	3		6	8	8.13	7.61	3.26	3.78	2.5	5
7	5	5.03	1.68	1.34	1.43	3.8	5		7	—	—	—	—	—	—	8*
8	5	5.31	4.92	1.83	2.28	2.9	3		8	3	2.90	6.04	1.06	2.37	2.7	5
9	7	7.03	6.74	.68	.86	10.3	5		9	5	14.77	9.44	7.48	8.40	2.3	5
10	5	2.93	3.94	.43	.26	6.8	1		10	—	—	—	—	—	—	19*
Av.	4.0	6.06	5.25	1.65	1.69	6.8	3.6		Av.	4.3	7.68	6.58	4.41	5.10	1.9	4.1
		(86%)		(102%)							(86%)		(138%)			

* Number of collisions in Series 8.

As Table III shows, two of these four (B_2 and B_7) improved slightly during the series. They reduced the number of collisions from maxima of 18 and 24 to 12 and 8, respectively. The other two (B_3 and B_{10}) made practically no improvement. From maxima of 30 collisions in Series 1, the number of their collisions continued high, falling only to 24 and 19, respectively, in Series 8. The six remaining *S*s of this group reached our criterion of learning: B_4, B_5, and B_8 in Series 3; B_1 in Series 4; B_9 in Series 5; and B_6 in Series 8. Of these *S*s, four possessed normal hearing in at

TABLE III

NUMBER OF COLLISIONS IN SUCCESSIVE SERIES IN EXPERIMENT 1

Group A (blindfolded only)

S	Series 1	2	3	4	5	6	7	8
1	15	4	(0)	(1)*				
2	10	2	(2)	(2)				
3	27	25	30	23	17	20	8	5
4	13	11	5					
5	7	3	(2)	(1)				
6	6	(0)	(0)					
7	14	15	17	11	5			
8	19	21	12	10	3			
9	29	24	24	13	23	17	5	
10	30	23	14	9	1	(2)	(2)	

Group B (blindfolded and deafened)

S	Series 1	2	3	4	5	6	7	8
1	12	9	9	4				
2	10	12	15	13	9	12	11	12
3	30	28	22	22	27	25	22	24
4	6	6	3					
5	17	6	5					
6	30	25	19	17	19	14	9	5
7	24	23	16	13	20	15	17	8
8	27	22	5					
9	17	21	14	11	5	(6)		
10	30	25	19	23	22	18	20	19

* Numbers in parentheses are collisions made in series given after criterion had been reached.

least one ear and two (*B_8* and *B_9*) had defective hearing, particularly at the higher audible ranges, in both ears.

Performance in Additional Series

To determine whether the *S*s had really learned to perceive obstacles or had merely met our criterion by chance, we gave five members of Group A (A_1, A_2, A_5, A_6, and A_{10}) and one of Group B (B_9) additional series of trials. All the *S*s from Group A were, as shown in Table III, consistent in their performances; once they had met criterion they continued to meet it.

For example: A_1, who reached criterion in Series 2 with 4 collisions, made 0 and 1 collision in Series 3 and 4, respectively; and A_{10}, who reached criterion in Series 5 with 1 collision, made 2 and 2 collisions in Series 6 and 7, respectively.

The *S* from Group B, who reached criterion in Series 5 with 5 collisions, was unable to duplicate his performance in Series 6. Since additional series were to be given in Experiment 2, further

tests of this kind were not made. These results suggest, however, that the depth of learning is not as great among the *S*s of Group B as of Group A.

Course of Learning

The course of learning for the *S*s of Group A, as measured by the reduction in the number of collisions, was, by and large, sudden or insightful. It was marked, as Table III shows, by an abrupt drop to criterion.

For example: A_1 collided with the obstacle 15 times in Series 1 and only 4 times in Series 2; A_2 collided 10 and 2 times in the two series with him; A_9 collided 29, 24, 24, 13, 23, 17, and 5 times in the eight series with him; and A_{10} made 30, 23, 14, 9, and 1 collisions in the five successive series with him.

After trying various unreliable cues, the *S*s apparently hit upon one that enabled them to reduce immediately the number of their collisions. Of the six *S*s reaching criterion from Group B, three reached it suddenly and three gradually. For example: B_8, a sudden learner, made 27, 22, and 5 collisions in successive series; B_6, a slow learner, made 30, 25, 19, 17, 19, 14, 9, and 5.

Judgments

The *S*s of Group A not only met our criterion of learning, but their performances, both in the series in which they first met it and in the series thereafter given them, also indicated that they were basing their judgment upon the obstacle. As Table II shows, their 'first perceptions' and 'final appraisals' differed from each other by considerable amounts. Their performance ratios (p/a) average 4.5 ± 1.86 with individual ratios varying from 1.5 to 10.3, which are values very like those obtained from normal, blindfolded *S*s in the earlier studies (see Supa, Cotzin, and Dallenbach, pp. 21-22; and Cotzin and Dallenbach p. 123). These values are very different, however, from those obtained by the *S*s meeting criterion from Group B whose ratios averaged 1.9 ± 0.56 with individual ratios varying from 1.1 to 2.7.

Collisions

For the *S*s of Group A, the number of collisions of the first and second types - pre- and post-'first-perception' collisions - decreased with learning until finally, when criterion had been reached, collisions of the third type - 'final-appraisal' collisions - were the only ones being made. These collisions occurred when *S* was attempting to improve his performance; when he was inching up to the obstacle which he knew was immediately before him. These cases were recorded as 'collisions' but in reality they were not 'failures' because the *S*s were aware, as indicated by their be-

havior and later reports, of the presence and nearness of the obstacle. The collisions of the *S*s of Group B after they had reached criterion were, on the contrary, chiefly of the second type - that is, post-'first-perception' collisions. After detecting the obstacle in their 'near approaches,' they rarely risked collisions by attempting to better their positions.

Standard Deviations

The standard deviations of the 'first perceptions' and 'final appraisals' are large for the *S*s of both groups, being 86 percent and 102 percent of the means of these performances respectively for Group A and 86 percent and 138 percent respectively for Group B. That the standard deviations should be large is not surprising as the conditions under which the *S*s of both groups served were highly complex and variable. That they should be larger for Group B than for Group A is due in part, as we believe, to the dependence of the *S*s of Group B upon more variable and fluctuating cues which resulted in 'good' performances when present and 'poor' performances when absent; and in part to a limitation of the distance that they walked in rendering their judgments - a point discussed below.

Discussion

The *S*s of neither group learned as rapidly as the *S*s in the Cornell studies who served indoors, and their performances (both 'first perceptions' and 'final appraisals') were more variable, as shown by the size of the standard deviations than those of the Cornell *S*s. Delay in learning and greater variability in performance are both due, as we believe, to the greater complexity of conditions out of doors. The ambient noises of the experimental area partially masked and at times totally obscured the sounds of *S*'s footsteps. Learning to perceive obstacles would, therefore, be delayed as more trials would be required under these unfavorable conditions for *S* to discover and to utilize the auditory cues necessary for the perception of obstacles than under the relatively noiseless conditions indoors in the laboratory. The adventitious noises of the experimental area out of doors, such as the sounds of pneumatic hammers from nearby construction, totally obliterated at times the cues upon which *S* based his judgments. If, therefore, the noise level was high when *S* reached a critical point in a trial, his performance would be worse than usual; if, on the other hand, the noise level chanced to be low, his performance would be better than usual. Chance variations in noise level, such as our *S*s experienced, would necessarily result in large variations in performance - such as our *S*s yielded.

The problem of learning to perceive obstacles out of doors was further complicated by the wind, the sun, and the clouds. These agencies produced cues at times that were used as the basis of our *S*s' judgments - especially those of Group B. On occasions when

there was a wind and *S* walked with or against it, he was made aware of the obstacle by changes in pressure against his face. When he walked into the wind, he could tell he was coming close to the obstacle by a drop in the pressure as the obstacle acted as a shield. When he walked with the wind, he could tell that the obstacle was near by the air currents reflected from it. When the wind died down, or blew across *S*'s path, these cues were, of course, absent and performance based upon them suffered.

When the sun shone hot, the obstacle was detected by temperature changes; either by a drop when *S* walked into its shadow, or by a rise when the sun shone upon it and its heat was reflected to *S*'s face as he neared it. The sun also yielded odors by means of which the obstacle could be detected. Although the masonite board was chosen in the first Cornell study because it was odorless indoors (see Supa, Cotzin, and Dallenbach, footnote 2, p. 51), it gave off a distinct odor out of doors in the hot sun. *S* could tell by the sense of smell alone when he was near the obstacle. On a cloudy day, or when the sun receded behind a cloud, the temperature cues were lacking. The olfactory cues were also lacking on a cloudy day, but the recess of the sun behind a cloud did not immediately bring about a cessation of the odor or the heat of the board. Those cues lingered and were effective as long as the board retained its heat.

Any of these cues was at times sufficient for the perception of the obstacle and all, particularly during the early stages of learning, were used by the *S*s. Like the proverbial drowning man and the straw, our *S*s grasped at any and every cue that would serve them. (For other 'straws,' see Supa, Cotzin, and Dallenbach, pp. 16, 27, and footnote 1, p. 51.) Although the cues from the wind and sun were at times sufficient, they were neither necessary nor always present. That they were used when available accounts, in part at least, for our *S*s delay in learning - that is, in discovering and utilizing cues (auditory) that were sufficient under most conditions - and for the large variability, shown in Table II, in their performances.

The *S*s of both groups knew that an obstacle was in the experimental path. This was so at every trial; there never was an exception in Experiment 1. If *S* had not collided with it before giving his 'final appraisal,' he was led up to it that he might know how far he was away from it. In every trial, therefore, the presence of the obstacle was confirmed. Although encouraged to approach the obstacle "as closely as possible" in his 'final appraisal,' an *S*, even though he lacked a reliable cue, would soon learn that a 'far' performance not only escaped the punishment of a collision but that it also equaled a 'close' performance in being counted as a 'success.' If an *S* were, therefore, to walk 8 to 10 ft, raise his right arm, signifying his 'first perception,' and then advance a little less than 4 to 2 ft and raise his left arm, signifying his 'final appraisal,' his 'first perceptions' would average 10.5 ±

6.5 ft; his 'final appraisals,' 8.5 ± 6.5 ft; his performance ratio would be 1.2; and he would collide with the obstacle only 6 times - results that are very similar to those of B_1 who met our criterion of learning with the following performance: average 'first perceptions,' 10.97 ± 8.17; average 'final appraisals,' 9.19 ± 8.52; performance ratio, 1.1; and collisions, 5.

Conclusions

The results of Experiment 1 indicate that:

1. blindfolded *S*s possessing normal or near normal hearing (Group A) are able to acquire the ability to perceive obstacles under the complex and varying conditions met out of doors; and

2. some blindfolded *S*s with impaired hearing (six members of Group B) are able, by methods undetermined, to avoid collisions with the obstacle.

We cannot, from the results at hand, determine the basis of the performances of the *S*s who met our criterion. Experiment 1 was an experiment in learning. We could not introduce any condition that would interfere with the process of learning. Now, however, that we knew the *S*s of both groups learned something, we could safely set conditions to discover what they learned and what cues they employed. Experiment 2 was the first of several undertaken for this purpose.

Experiment 2

The object of Experiment 2 was to determine what precisely the *S*s had learned in Experiment 1. We wished to discover whether they had really learned to perceive the obstacle - that is, had based their performances upon cues derived from it - or had merely learned to avoid collision by restricting, consciously or unconsciously, the distances they walked in making their reports.

Procedure

In every respect but two the procedure was the same as in Experiment 1. The new conditions were the following:

1. check trials, in which there was no obstacle in the experimental path, were introduced into the experimental series; and

2. *S*, unless he collided with the obstacle, served without knowledge of his results, as

he was given no information about his performances and was not permitted to extend his hand to confirm the accuracy of his 'final appraisals.'

Since this experiment was a test to determine what was learned and not to aid learning, only one series of 30 trials was given each of the *S*s. This series consisted of 20 trials in which the obstacle (the one used in Experiment 1) was placed in the experimental path and 10 trials in which it was not present. The obstacle distances and the starting points were the same as in Experiment 1.

The check trials were randomly distributed through the obstacle series. None of the *S*s knew that they were to be given. When used, *S* was permitted to walk the entire length of the experimental path (60 ft) if he did not report a 'final appraisal' before reaching that point. From the end of the path, *S* was led without comment back to the starting point for the next trial - just as was done when he gave his 'final appraisals' or had collided with the obstacle.

Subjects

All the *S*s of Groups A and B who met our criterion of learning in Experiment 1, and B_2 and B_7 who showed progressive improvement, served in Experiment 2. B_3 and B_{10} were excused from this part of the study because their results gave no evidence of learning of any kind.

Instructions

Since *S* was no longer to be led to the obstacle after his 'final appraisals' and would not be permitted to extend his arms to test the accuracy of his judgments, the instructions were so modified that he would not suspect the purpose of the change in procedure. They were as follows.

> "We believe that you have learned to perceive obstacles. Now, after raising your left hand indicating that you are as close as you possibly can come to the obstacle without touching it, you will no longer be be led up to it. Do not reach out to verify your judgment after you had given it because in this series we wish to determine how closely you can come to the obstacle without knowledge of your results."

Results

Group A

The results of Experiment 2, given in Table IV, show clearly that

TABLE IV

RESULTS OF EXPERIMENT 2

Mean Distances and SD (in Ft) of the 'First Perceptions' and 'Final Appraisals,' the Ratios of these Distances, the Number of Collisions, and the Number of Times Obstacles Were Reported in the Check Trials.

Group A (blindfolded only)

S	p M	p SD	a M	a SD	p/a	No. of collisions	No. of false reports
1	3.13	5.92	2.31	3.24	1.3	1	1
2	5.73	5.56	1.98	1.31	2.8	1	0
3	—	—	1.64*	2.06*	—	3	0
4	5.58	6.70	3.60	5.36	1.6	3	2
5	10.07	9.27	6.13	5.48	1.6	3	1
6	4.36	7.05	1.67	3.20	2.6	1	2
7	10.07	9.27	6.13	5.48	1.6	5	0
8	9.47	7.26	4.18	6.09	2.3	3	2
9	3.07	3.06	1.98	.85	1.6	3	0
10	2.70	.69	.48	.58	5.6	1	0
Av.	6.02	6.09 (101%)	3.34	3.74 (112%)	2.3	2.4	0.8

Group B (blindfolded and deafened)

S	p M	p SD	a M	a SD	p/a	No. of collisions	No. of false reports
1	10.28	7.90	6.99	7.62	1.5	3	10
2	3.44	7.16	2.30	5.31	1.5	10	1
3	—	—	—	—	—	—	—
4	—	—	1.22*	2.33*	—	3	0
5	6.46	8.80	4.64	7.50	1.4	1	5
6	6.71	6.21	1.70	2.19	3.9	15	1
7	6.25	3.46	2.14	1.88	2.9	13	4
8	2.66	.99	.38	.31	7.0	9	0
9	10.72	8.72	8.56	7.92	1.3	4	10
10	—	—	—	—	—	—	—
Av.	6.65	6.18 (93%)	3.8[illegible]	4.81 (126%)	2.6	7.2	3.9

* Results not included in the averages because 'first perceptions' were not reported.

the judgments of the *S*s of Group A were based upon cues derived from the obstacle. Five of them (A_2, A_3, A_7, A_9 and A_{10}) made no errors in the check trials - that is, they did not report the obstacle when it was not there; two (A_1 and A_5) made only one, and three (A_4, A_6, and A_8) made but two. (In this respect the performances of the five *S*s out of doors equaled those of the Cornell *S*s indoors; see Supa, Cotzin, and Dallenbach, pp. 22 and 26.) The *S*s were under the instruction to perceive an obstacle which they had learned in the previous experiment would always be in the path. That only half of them reported it under those circumstances, and that they reported it only once or twice out of 10 check trials, is indication that their perception of obstacles is so compulsory that it cannot easily be replaced by imaginal components.

Their collisions, which varied in number from 1 to 5 (four *S*s made 1 each, five made 3 each, and one made 5), were all of the 'final appraisal' type, made while attempting to better their records, hence their collisions in no way detract from the high quality of their performances. It is true, as a comparison of Tables II and IV reveals, that their performances (means and standard deviations of their 'first perceptions' and

'final appraisals') were poorer than in the criterion series of Experiment 1, but the differences are not great and are due, as we believe, to the fact that they were working without knowledge of their results.

One of these *S*s, A_3, who made no false reports and had only three collisions, stopped his approach at the 'first perception,' or rather his 'first perception' was also his 'final appraisal.' The average differences between these reports in Experiment 1, where the instructions called for two reports in every trial, were only a little over a foot - about half a step (see Table II). In the test series we permitted *S* freedom in report and A_3 chose to give only one judgment in every trial.

Group B

The *S*s of Group B present again a very different picture. Two of them (B_1 and B_9) failed utterly. They reported 'first perceptions' and 'final appraisals' in every one of the check trials. Although they collided with the obstacle only 3 and 4 times, respectively, it is clear that they had merely learned in Experiment 1 to avoid collisions - not to perceive obstacles. When questioned at the conclusion of the test series, neither was able to describe the basis of his judgments. The means and standard deviations of their performances suggest, however, that they were merely limiting the distances walked in approaching the obstacle. We do not believe that they did this consciously as a planned procedure but rather that they arrived at it by trial and error as a means of escaping the punishment of the collisions.

Two members of this group (B_4 and B_8), on the other hand, made no false reports in the check trials. Though they collided with the obstacle 3 and 9 times, respectively, the fact that they did not report the obstacle when it was not present is evidence that their judgments were based upon it. Their collisions, moreover, were chiefly of the 'final appraisal' type. Indeed, B_4, like A_3, refused in this experiment to report 'first perceptions' - or rather, her 'first perceptions' were her 'final appraisals.' In Experiment 1, in which she was required to give two reports in every trial, her 'first perceptions' (see Table II) were given only a few inches before her 'final appraisals.'

As Table I shows, B_4 possessed normal hearing in both ears and B_8 had normal hearing in his left ear except at the highest audible range tested (11,584 Hz). Both of these *S*s were, moreover, among those of Group B reporting that they could at times hear their footsteps despite our efforts to deafen them. How these two *S*s detected the obstacle, we cannot definitely say, but that they had learned to detect it is clearly demonstrated, as we believe, by

their result in this experiment.

The results of the *S*s we have thus far considered are definite and decisive; now we come to *S*s whose results are ambiguous. B_2 and B_6 reported the obstacle once each when it was not present - 9 times they avoided failure in the check trials. One failure was not regarded as sufficient to question the ability of the *S*s of Group A; hence the ability of B_2 and B_6 would not be questioned if it were not for the fact that they made 10 and 15 collisions, respectively, in the 20 trials with the obstacle. Such large percentages of collisions (50 and 75, respectively) are hardly indicative of the 'obstacle sense.' Their performances (means of their 'first perceptions' and 'final appraisals'), despite their large variations (standard deviations), do not, however, appear to be dictated by change nor by a limitation of the distances walked during the trials. They seem, rather, to be the result of variable cues (wind and temperature reflections from the obstacle, odors derived from it, shadows cast by it, and sounds echoed from it during fortuitous drops in the level of the ambient noises) which were adequate in varying degrees when conditions permitted them to be noticed. If such were the case, results like those given by these *S*s would be obtained. Every time these cues were absent, *S* would continue walking until he collided with the obstacle or reached the end of the experimental path. This would mean if these cues were frequently lacking, a large number of collisions and few errors in the check trials. B_4 and B_6 must, therefore, as we believe, be credited with learning to perceive obstacles - at least at a low level, but low only because their hearing was obstructed. If their hearing were unobstructed, they would, we predict, be facile in the perception of obstacles.

The records of the two remaining *S*s of Group B (B_5 and B_7)are still more difficult to interpret. B_5 made 1 collision and 5 errors in the check trials. The errors in the check trials (50 percent) suggest chance, but his performances in the trials in which the obstacle was present negates that conclusion. The mean of his 'first perceptions' is good, but the means of his 'final appraisals' and his performance ratio (p/a = 1.4) are poor. The standard deviations of the means of his performances are high (being 136 and 162 percent, respectively) and suggest that the cues upon which his performances were based were not dependable. B_5 possessed normal hearing in one ear (see Table I); hence it may well be that he, like B_2 and B_6, reacted to cues that were so highly variable and weak that they were easily imagined. Upon the basis of these assumptions, we may credit B_5 as being among those in Group B who learned to perceive obstacles, although at an extremely low level.

B_7 made 13 collisions and 4 errors in the check trials, just about what would be expected by chance. His results indicate that he failed in learning to perceive obstacles and, furthermore, that

he also failed, as his numerous collisions (65 percent) attest, in learning to avoid them. He was, as will be recalled, one of the two *S*s included in this experiment who failed to meet our criterion of learning in Experiment 1. B_2, the other *S* included under like conditions, demonstrated, as shown above, that he had learned something, but B_7 cannot be credited with learning anything other than the sheer mechanics of the experiment. He must, therefore, be classified with B_3 and B_{10} who gave no evidence in Experiment 1 of learning anything about obstacle perception.

Summary and Conclusions

As these results show, all the *S*s of Group A and half of those of Group B (B_2, B_4, B_5, B_6, and B_8) demonstrated that they had learned to perceive obstacles - that is, to localize them from cues derived from them. Not all of the *S*s meeting our criterion of learning in Experiment 1 were able, however, to do this. Two from Group B (B_1, and B_9, see Table II), who had met criterion were not able in Experiment 2 to differentiate between the check and the obstacle trials. They had not learned to perceive the obstacle but had merely, learned, as Worchel and Dallenbach's deaf-blind *S*s had done, to avoid collisions by limiting the distances they walked (see pp. 77-78). Contrariwise, one *S* (B_2), who failed to meet our criterion in Experiment 1, demonstrated that he had acquired the ability by distinguishing between the presence and absence of the obstacle.

These results demonstrate the necessity of check trials in experiments of this nature in determining who learned and what they learned. Now that we have the answers to these questions, we may turn to discovering what cues were used by the *S*s as the basis of their judgments.

Experiment 3

Most of the *S*s of both groups had at one time or another during the preceding experiments mentioned that they detected the obstacle - a masonite board - by its odor when they came close to it. Although this board was originally selected as the obstacle because it was odorless indoors, it did, as mentioned previously, give off a distinct odor when it stood in the heat of the sun. Experiment 3 was undertaken to determine the role played by smell. If an *S* detected the obstacle by smell, then the elimination of that modality of sense should immediately show itself in an increase in the number of his collisions, or in the distance of his 'final appraisals,' or both.

Method and Procedure

Holding all other conditions of Experiment 2 constant, smell was

eliminated by plugging *S*'s nostrils. Cotton wool was inserted in *S*'s anterior nares and covered and held in place by strips of adhesive tape. If any odor penetrated the plugs it was the constant odor of the tape. The experiment consisted of one series of 30 trials - 10 check trials randomly distributed among 20 obstacle trials.

Subjects

Only three *S*s (A_9, A_{10}, and B_8), who mentioned the odor of the board most frequently, were used. All of them had met criterion in Experiment 1 and all had demonstrated in Experiment 2 that they perceived and reacted to the obstacle.

Results and Conclusions

The nasal plugs did not adversely affect the performances of any of the *S*s. Their performances equaled those in Experiment 2 in which the olfactory cues were available to them. A_{10}, for example, gave the following results: $p = 2.50 \pm 0.86$; $a = 0.66 \pm 0.67$; $p/a = 3.8$; 3 collisions; and 0 false reports. A comparison of these results with those given by him in Experiment 2 (see Table IV) reveals no significant differences. The records are of a kind. As with A_{10}, so also with the other *S*s. Both hearing and deafened *S*s seemed to be unaffected in their performances by the loss of smell.

By the time of this experiment, all the *S*s were highly practiced and proficient in the perception of obstacles. It may well be, therefore, that smell, although significant in the early stages of learning, had been replaced at our *S*s' level of training by more dependable cues that were always present and always available. However this may be, the results of this experiment led us to conclude that odor is not a necessary condition for the perception of obstacles, although at times it may be sufficient - particularly during the early stages of learning before more subtile and reliable cues have been discriminated and assimilated. Few obstacles yield an odor - our masonite board did only now and then when under the heat of the sun - hence an *S*, if he acquired the ability to perceive obstacles, must discover and rely on cues that are more universal and dependable.

Experiment 4

Experiment 4 was a repetition of Experiment 2 under the darkness of night. It was undertaken to eliminate various factors that seemed to be inherent in the experiments conducted during the day. These factors - that is, the experience of "blackness" and temperature and olfactory changes - were reported by all the *S*s, who learned to perceive obstacles, as cues of their final appraisals.

The "blackness" reported may be visual experiences derived from the sun. Although we found that our blindfolds were light-proof when tested in the laboratory, the intensity of the light used (a 200-W lamp) is hardly comparable with that of the sun; hence it is possible that the *S*s were discriminating visually when they passed from the light of the sun into the deep shadow of the obstacle in their near approach of it. Temperature changes - an increase by reflection or convection from the obstacle, or a decrease when *S* stepped into the obstacle's shadow - and the smell of the board are cues that also derived from the sun.

All of these factors were immediately eliminated by conducting the experiments at night. In addition, night work reduced the intensity of the ambient noises because neighboring construction had temporarily ceased and traffic in the street and through the campus had greatly lessened. By working at night and observing the effect upon *S*'s performances, we hoped to be able to evaluate the significance of these factors in the perception of obstacles. If there is a decrement in *S*'s performances, their value will be demonstrated; if there is no significant difference in performance, little or no value may be attached to them; and if there is an increment in performance, their insignificance, in comparison with the auditory cues which emerge with the reduction of the surrounding noise level, will be revealed.

Procedure

The procedure was the same as that of Experiment 2 with the exception that the series of 30 trials (10 check interspersed among 20 obstacle trials) was conducted between 8 and 10 p.m. Though this series was conducted during December, there was sufficient light at the experimental area for the *E*s, after being dark adapted, to discern the starting points, the obstacle placements, and the distances traversed by the *S*s without the aid of special illumination.

Subjects

All the *S*s of Group A, except A_8, and six *S*s of Group B served in this experiment. Of the six *S*s of Group B, four demonstrated in Experiment 2 that they had learned to perceive obstacles; one (B_7), that his judgments were chance; and one (B_9) that he had learned merely to avoid obstacles, not to perceive them. B_7 and B_9 were included in the hope that we might be able to discover the cause of their previous failures.

Instructions

The instructions were the same as in Experiment 1 except for the addition of the following sentence: "We wish to see how well you can perceive obstacles at night."

Results

Group A

The results of this experiment are given in Table V. As a comparison of this table with Table IV reveals, all the *S*s of Group A

TABLE V

RESULTS OF EXPERIMENT 4

The Mean Distances and SD (in Ft) of the 'First Perceptions' and 'Final Appraisals,' the Ratios of These Distances, the Number of Collisions, and the Number of Times Obstacles Were Reported in the Check Trials.

Group A (blindfolded only)

S	*p*		*a*		*p/a*	No. of collisions	No. of false reports
	M	*SD*	*M*	*SD*			
1	1.79	2.82	.54	.74	3.3	2	0
2	3.00	2.41	.68	.78	4.4	0	2
3	2.00	1.90	.29	.24	7.1	5	0
4	3.11	2.76	.31	.16	10.0	5	2
5	5.36	4.63	.63	1.62	8.5	5	0
6	1.83	2.83	.48	.49	3.8	3	1
7	4.94	2.22	2.46	1.31	2.0	5	0
9	2.70	3.06	.43	.45	6.3	5	0
10	4.76	3.99	.56	.53	8.5	0	0
Av.	3.08	2.96 (96%)	0.71	0.74 (104%)	6.0	3.3	0.55

Group B (blindfolded and deafened)

S	*p*		*a*		*p/a*	No. of collisions	No. of false reports
	M	*SD*	*M*	*SD*			
2	6.76	5.42	1.71	2.34	3.9	9	2
4	.97	1.84	.87	.84	1.1	11	0
6	16.65	9.39	11.00	6.35	1.5	14	10
7	10.71	6.66	8.56	6.51	1.3	10	5
8	2.63	3.22	1.00	.85	2.6	2	1
9	12.46	8.67	5.79	6.59	2.1	5	2
Av.	8.36	5.87 (71%)	4.84	3.91 (81%)	2.1	8.5	3.33

improved their performances at night. Their performance ratios are larger (averaging 6.0 as against 4.5), the means of their 'final appraisals' are much smaller (being for eight of the nine *S*s between 3 and 8 in.),[3] and their records in the check trials are better (six *S*s made no errors, one made 1, and two made 2). Their collisions, though slightly more numerous (averaging 3.3 against 2.4) were all of the third type - that is, made during the 'final appraisal.'[4]

The conditions at night were beneficial to the *S*s of Group A. The accuracy of their judgments was unaffected by the loss of the cues dependent upon the sun - unless the elimination of their distracting influence be regarded as a contributing factor. The improvement made by all of these *S*s is primarily due, as we believe, to the reduction of the intensive level of the ambient noises which permitted more accurate discrimination among the auditory stimuli.

Group B

The picture is again very different for the *S*s of Group B. The conditions at night variously affected them. The performances of two (B_6 and B_7) suffered a marked decrement. Their performance ratios (p/a) were smaller than during the day, falling to 1.3 and 1.5 from 2.9 and 3.9, respectively; their 'final appraisals' were much greater, being from 4 to 6 times as large; and the number of their collisions and false reports being altered, by and large, for the worse. B_6 was counted, upon the basis of his results in Experiment 2, as being among those demonstrating that they had learned to perceive obstacles - that is, his judgments were based upon cues derived from the obstacle. With 14 collisions and 10 false reports in the present experiment, he clearly demonstrated his dependency upon the daytime cues - without them he failed utterly. The results of the second of these *S*s (B_7) confirm our previous judgment; namely, that he had learned nothing of the perception of obstacles. His records in Experiment 2 and here denote failure, hence the decrement here is probably due to chance variations and not to the loss of cues that proved to be of no value to him in Experiment 2.

Two members of Group B (B_4 and B_8) gave results that varied but little from those in the daytime trials; hence we may safely assume that the cues available during the day were of slight if of any significance to them. The only cues available in this experiment were wind pressures and sounds. Since wind pressures are fortuitous and the *S*s' performances were not, we can only conclude that the *S*s were reacting to auditory cues in Experiment 2 as well as in this experiment. That there was no change in their results follows from the fact that there was for them no change in the experimental conditions.

The two remaining *S*s of Group B (B_2 and B_9) bettered their performances; B_9 slightly and B_2 markedly (see Tables IV and V). B_9 was one of the *S*s meeting criterion in Experiment 1 who demonstrated in Experiment 2 that he had learned nothing about the perception of obstacles but merely how to avoid collisions. He showed here, however - by increasing his performance ratio to 2.1 from 1.3 and reducing his false reports to 2 from 10 - that he was beginning to learn and that under the more favorable conditions at night reliable cues of the obstacle were available. B_2, on the other hand, showed a marked improvement. His performance ratio was increased from 1.5 to 3.9, and, except for the large number of collisions, his results are more like those of Group A than of Group B. This result is surprising because the analysis of his results in Experiment 2 revealed that he was responding in that study to the very cues that were eliminated in this one. B_2 had normal hearing, however, in both ears; it is probable, therefore, that the reduction in the noise level at night permitted him for

the first time to notice and to use the auditory cues. Since most of his collisions occurred during the early trials and he shuffled his feet along the walk and commented upon the changes in their sounds more and more as the experiment progressed, the explanation of his results in terms of his discovery and utilization of auditory cues has a high degree of plausibility. However this may be, it is certain that his performance in Experiment 4 did not suffer because of the lack of the daytime cues upon which he seemed to depend in Experiment 2.

Verbal Reports

Some of the *S*s of Group A again reported experiences of "blackness" ("a black curtain," "a dark shade," and the like) when they neared the obstacle. Since there was no possibility of visual stimulation under the conditions of this experiment, these experiences must be regarded as imaginal and as being aroused associatively by cues which marked the presence of the obstacle. These cues were probably auditiory, at least in the present experiment, because many of the daytime cues were eliminated and audition was enhanced by the reduction in the surrounding noise level.

All the *S*s of Group A, and some of Group B who could hear the sound of their feet as they shuffled them along the sidewalk, commented upon the changes in sound of their footsteps as they approached the obstacle. For many this was an old story, but for some it was new. For all, however, Experiment 4 offered the best opportunity, by virtue of the reduction of the surrounding noise level, for the observance of the auditory cues.

Summary and Conclusions

As these results show, only one *S* (B_6), who had demonstrated his ability to perceive obstacles, suffered a decrement in his performance under night conditions. All the *S*s of Group A and two of Group B bettered their performances considerably; the remaining *S*s showed little or no change. Since the elimination of the daytime cues was accompanied by a reduction in the noise level of the experimental area, the improvement in *S*s' records is due, as we believe, to the increased effectiveness of the auditory cues. These results show the importance of audition and indicate that thermal and olfactory cues, although sufficient under some conditions, are not necessary for the perception of obstacles.

Since "black curtains" and "dark shades" were again reported by the hearing *S*s (Group A) under conditions impossible for visual stimulation, we conclude that these experiences are imaginal, being aroused associatively by auditory cues which mark the presence of the obstacle.

PART II

Part II is a repetition of Part I with an interchange of the experimental conditions between the two groups of *S*s. The *S*s of Group A were now blindfolded and deafened; those of Group B were blindfolded only. Short of doing this, we could not be certain that the differences between the results of the two groups in Part I were due to the experimental conditions and not to individual differences. By interchanging the experimental conditions, each group served as its own control.

Experiment 5

Experiment 5 was a repetition of Experiment 1 - an experiment in learning. The procedure, instructions, and *S*s of the two groups were the same with the single exception, mentioned above, that the experimental conditions under which the two groups served were interchanged. We repeated this experiment to teach the *S*s to perceive obstacles under the new conditions and also to see whether they would learn more or less rapidly, because of their previous training, than the comparable group in Experiment 1. What would be the effect of giving *S*s hearing who had previously been deprived of it; and, conversely, what would be the effect of depriving *S*s of hearing who had previously been accustomed to it?

Results

Group A

With one exception, all the *S*s of Group A, now the deafened group, learned under the new conditions to perceive the obstacle (see Table VI). The immediate effect of impairing their hearing was a great increase in the number of their collisions, but learning proceeded rapidly and within three series all but one *S*, A_g, had attained criterion (25 successes in 30 trials - that is, five or fewer collisions).

The single exception, A_g, was unable to learn within the trial limits of this study; he collided with the obstacle 15 times in the final series and from 13 to 15 times in the preceding series. As Tables II and III show, he was a slow learner, requiring seven series to reach criterion in Experiment 1. This was possibly due to the fact that he had a 50-dB loss in both ears at 11,584 Hz (see Table I) and required, because of it, more practice than the other *S*s to meet criterion. Once it was met, however, he was a good performer as his records in the other experiments of Part I clearly indicate. His inability to meet criterion in the present experiment is due, as we believe, to the successful impairment of his hearing. With ears plugged, his threshold was 65 dB at 8192 Hz and 90 dB at 11,954 Hz. Since the noise level of the experimental area varied between 30 and 70 dB, he was without doubt totally deaf to these

TABLE VI

RESULTS OF EXPERIMENT 5

The Number of Series Required by the *S*s of Each Group to Reach Criterion, the Mean Distances and SD (in Ft) of the 'First Perceptions' and 'Final Appraisals,' the Ratios of These Distances, and the Number of Collisions in the Series in Which Criterion was Reached.

Group A (blindfolded and deafened)							
S	No. of series required for criterion	*p*		*a*		*p/a*	No. of collisions
		M	*SD*	*M*	*SD*		
1	3	1.93	3.40	.28	.15	6.9	2
2	1	3.37	6.34	1.11	3.91	3.0	3
3	2	2.66	3.81	.62	1.70	4.1	4
4	3	6.15	7.83	1.46	1.74	4.2	4
5	2	3.61	6.74	1.48	2.88	2.0	3
6	3	1.89	.96	.33	.65	5.8	2
7	2	5.96	1.82	1.66	1.79	3.6	3
8	3	11.07	7.51	4.34	6.14	2.5	5
9	—	—	—	—	—	—	15*
10	2	2.64	4.32	.62	2.14	4.2	3
Av.	2.33	4.36 (109%)	4.75	1.32 (177%)	2.34	4.0	3.2

Group B (blindfolded only)							
S	No. of series required for criterion	*p*		*a*		*p/a*	No of collisions
		M	*SD*	*M*	*SD*		
1	1	6.16	5.22	2.97	3.89	2.1	2
2	1	5.68	4.49	.96	1.81	5.9	2
3	4	6.18	6.49	1.52	1.48	4.0	5
4	1	—	—	1.18*	1.02*	—	3
5	1	6.70	6.04	3.29	4.02	2.0	5
6	2	6.45	7.61	1.30	4.55	4.9	5
7	1	4.00	4.39	2.46	3.79	1.6	3
8	1	3.04	1.50	1.26	.98	2.4	0
9	1	3.40	4.87	2.58	4.30	1.3	2
10	4	7.72	6.96	1.43	3.11	5.4	5
Av.	1.7	5.48 (96%)	5.28	1.97 (157%)	3.10	3.3	3.2

* Results not included in the averages.

higher frequencies - the very ones which are, according to Cotzin and Dallenbach, responsible for the perception of obstacles (see pp. 141, and 147-150).

The performances of all the other *S*s of Group A in the criterion series were good. As a comparison of Tables II and VI reveals, they are almost as good as when hearing was unimpaired. Criterion was met in fewer series (averaging 2.33 against 4.0); the performance ratios are almost as high (averaging 4.0 against 4.5); and the number of collisions in the criterion series is fewer (averaging 3.2 against 3.6). These results considered alone suggest that impairment of hearing interfered but little, if at all, with the ability of these *S*s to perceive obstacles; but considered alone they are misleading. They merely show that the *S*s, despite the impairment of their hearing, had regained their former ability.

The immediate effect of the impairment of hearing was, as we observed above, to increase greatly the number of collisions. From relatively few collisions, the *S*s made many as soon as hearing was impaired (see Series 1, Table VII). That they were able with very little practice to reduce the number of collisions to criterion indicates that they either found other cues or were successful in reinterpreting the auditory cues still available. We are inclined to the latter view because all the *S*s of this group

TABLE VII

NUMBER OF COLLISIONS IN SUCCESSIVE SERIES IN EXPERIMENT 5

Group A (blindfolded and deafened)					Group B (blindfolded only)				
S	Series				S	Series			
	1	2	3	8		1	2	3	4
1	16	14	2		1	2	(2)		
2	3	(1)*	(1)		2	2	(1)		
3	15	4			3	18	14	13	5
4	9	7	4		4	3	1		
5	6	3			5	5	(5)		
6	7	11	2		6	15	5		
7	21	3			7	3			
8	12	6	5		8	0	(2)		
9	15	13	15	15	9	2			
10	10	3			10	17	10	10	5

* Numbers in parentheses are collisions made in series given after criterion had been reached.

shuffled their feet along the sidewalk during their approaches - some rather vigorously[5] - which none of them had done before their hearing was impaired.

Group B

All of the *S*s of Group B met criterion very quickly under the new conditions (see Table VII). Of the six *S*s attaining it in Experiment 1, five (B_1, B_4, B_5, B_8, and B_9) attained it again in this experiment in Series 1 and one (B_6) in Series 2. Of the four *S*s failing to reach criterion in Experiment 1, two (B_2 and B_7) now attained it in Series 1 and two (B_5 and B_{10}) in Series 4.

Despite the instructions, B_4 persisted in the habit, acquired during the experiments in which she was deafened, of reporting only once during a trial. When pressed to give two reports in this experiment - a 'first perception' and a 'final appraisal' - she advanced infinitesimally and reported again; hence we once more permitted her to have her way. She met criterion in Series 1, hence had little practice with hearing intact. Later, as Tables VIII and IX show, she willingly and accurately gave both of these judgments.

Performances in Additional Series

After meeting criterion, a few *S*s were given additional series of

trials to determine the constancy of their performances. As Table VII shows, all were constant; once meeting criterion, they continued to meet it.

Course of Learning

Insofar as the *S*s yielded results showing a course of learning - and not all of them did, as seven of Group B and one of Group A met criterion in Series 1 and one (A_9) was unable to meet it within the limits of our trial series - all learned suddenly or insightfully.

As Table VII shows, the number of collisions of the *S*s requiring two or more trials to reach criterion dropped abruptly: B_3 collided with the obstacle 18, 14, 13, and 5 times in successive series; B_6, 15 and 5 times; B_{10}, 18, 10, 10, and 5 times; A_1, 16, 14, and 2 times; A_3, 15 and 4 times; A_4, 9, 7, and 4 times; A_6, 7, 11, and 2 times; A_7, 21 and 3 times; A_8, 12, 6, and 5 times; and A_{10}, 10 and 3 times.

Comparison of these results with those of Experiment 1 (see Tables III and VII) reveals that the course of learning is similar for the groups with normal hearing and dissimilar for the groups with impaired hearing. The deafened *S*s in Experiment 1 seemed to learn gradually by trial and error, but in the present experiment they seemed to learn insightfully - that is, they reached criterion abruptly.

Judgments

From the results shown in Table VI, the judgments of of the *S*s of both groups seemed to be based upon the obstacle. The 'first perceptions' and 'final appraisals' differ by considerable amounts and the ratios of these performances are high, averaging 4.0 ± 1.1 for the *S*s of Group A, with individual ratios varying from 2.0 to 6.9, and 3.3 ± 1.6 for Group B, with individual ratios from 1.3 to 5.9. The distances traversed in giving these judgments seemed to be correlated with the distances of the obstacle from the starting points. None of the *S*s of either group seemed to be restricting the distances he walked.

Collisions

The collisions of the *S*s of both groups attaining criterion in Series 1 (see Tables VI and VII) were chiefly of the third type - that is, 'final appraisal' collisions. Of those requiring more series, and in particular of those colliding numerous times with the obstacle in Series 1, the collisions were at first of the pre- and post-'first-perception' types. As learning progressed, however, the types changed to the second and third types until final-

ly they were chiefly of the third. The collisions made by the hearing and the deafened *S*s were not differentiated as to type as they were in Experiment 1.

Standard Deviations

The standard deviations of the performances of the *S*s of both groups are much larger in this experiment than in Experiment 1 (see Tables II and VI). The average standard deviations of the 'first perceptions' and 'final appraisals' of the hearing *S*s were 86 percent and 102 percent, respectively, of the means of these reports in Experiment 1 (Group A) and 96 percent and 157 percent, respectively, in Experiment 5 (Group B). Of the deafened *S*s, the standard deviations were 86 percent and 138 percent, respectively, of the means in Experiment 1 (Group B) and 109 percent and 177 percent, respectively, in Experiment 5 (Group A). We are at a loss for an explanation of the greater variability of the reports in Experiment 5. The practice that the *S*s had had in the perception of obstacles since serving in Experiment 1 should have yielded smaller not larger standard deviations. The *S*s were, to be sure, serving under new conditions, but new conditions were no novelty because the *S*s had been continually meeting them in the successive experiments in Part I.

Two explanations of these results, both of which seemed reasonable and highly probable, were examined and found wanting. The first, the rapidity with which the *S*s reached criterion, rested upon the assumption that the standard deviation decreases with practice. Since the *S*s required twice as many series to reach criterion in Experiment 1 (4.0 and 4.3) as in Experiment 5 (1.7 and 2.3), the level of practice was lower in Experiment 5 than in Experiment 1; hence the standard deviation should be larger in Experiment 5 than in Experiment 1 - which is just what we found. If this explanation is true, then it should follow that the *S*s requiring the most series to reach criterion should have the lowest standard deviations. To test this hypothesis, the *S*s of both groups were divided into subgroups: Group A into those meeting criterion in the first or second series and those meeting it in the third series; and Group B into those meeting criterion in the first series and those meeting it in the second or later series. The explanation was substantiated by the results of Group A (the subgroup meeting criterion 'early' had standard deviations of 137 percent and 226 percent; the subgroup meeting criterion 'late' had standard deviations of 94 percent and 135 percent), but it was negated by those of Group B (the 'early' subgroup had standard deviations of 91 percent and 114 percent and the 'late' subgroup of 103 percent and 212 percent).

The second explanation, the rapidity of improvement of performance within the criterion series itself, rests upon the assumption that the *S*s improved so rapidly during the criterion series of the experiment that the early performances were very different

from the later; hence the standard deviations of the averages of all the performances would be large - just as we found them to be. If this explanation is true, the means of the performances of the first and the last 10 trials of this series should differ greatly. Unfortunately they do not.

It may be of course that the explanation lies in a change in the attitude of the *S*s toward the experiment. They may have become bored by it and resentful of our claims upon their time, hence indifferent in their performances. Although this conclusion does not necessarily follow from the premises, the *S*s gave us no evidence that their attitude had changed. They seemed to be as interested and as cooperative during this experiment as ever before.

Summary and Conclusions

With the exception of one member of the deafened Group (A_g), the *S*s of both groups, hearing and deafened alike, reached criterion quickly. The performances of all, even of those of A_g, showed clearly the importance of hearing. The *S*s of Group A, all of whom had learned to perceive obstacles with unimpaired hearing, immediately suffered a decrement in their performances when their hearing was impaired. This was marked at first and although it was soon overcome, by all except A_g, to a degree that permitted them to reach criterion, few attained their former level of competency, as indicated by the performance ratios. A_g, who was totally deafened by the ear blocks because of deficient hearing at the higher audible ranges, failed utterly. All the other *S*s of this group attempted to overcome the impairment of their hearing by increasing the intensity of the sounds from their footsteps. The *S*s of Group B, even those failing to attain criterion in Experiment 1, reached it quickly when hearing was restored to them.

The *S*s of both groups who met criterion seemed to base their judgments upon the obstacle. Although it is tempting to assume that they did and that they had learned, some for the first time and some for the second time, to perceive obstacles, caution dictates that this conclusion is not justified short of a test series with check trials. The next experiment is, therefore, indicated.

Experiment 6

Experiment 6 was conducted to determine whether the *S*s had learned in Experiment 5 to perceive obstacles or merely to avoid collisions. The experimental area, apparatus, procedure, and instructions were the same as in Experiment 2. Ten check trials were distributed haphazardly, as before, among 20 obstacle trials. All the *S*s of the deafened group (Group A),[6] which is the

more critical of the two groups because the basis of their judgments is less certainly auditory and 7 of the 10 *S*s of the hearing group (Group B, see Table VIII) served in this experiment.

TABLE VIII

RESULTS OF EXPERIMENT 6

Mean Distances and SD (in Ft) of the "First Perceptions' and 'Final Appraisals,' the Ratios of These Distances, the Number of Collisions, and the Number of Times Obstacles Were Reported in the Check Trials.

Group A (blindfolded and deafened)							
S	*p*		*a*		*p/a*	No. of collisions	No. of false reports
	M	*SD*	*M*	*SD*			
1	2.50	5.57	1.37	4.42	1.8	7	2
2	6.07	9.12	1.61	3.76	3.8	1	0
3	6.45	7.74	.75	.77	9.2	16	2
4	8.09	5.16	1.98	.66	4.1	9	9
5	4.14	5.62	1.24	.76	3.3	0	0
6	1.42	.22	.25	.00	5.7	3	1
7	4.10	1.30	1.93	1.08	2.1	2	0
8	7.21	1.88	3.98	1.11	1.8	6	6
9	3.20	4.13	2.18	1.92	1.5	13	0
10	1.92	.88	.95	.74	2.0	11	0
Av.	4.51	4.06 (90%)	1.62	1.52 (94%)	3.5	6.8	2.0

Group B (blindfolded only)							
S	*p*		*a*		*p/a*	No. of collisions	No. of false reports
	M	*SD*	*M*	*SD*			
1	6.24	4.32	1.28	1.05	4.9	4	1
2	.75	.78	.25	.00	3.0	1	0
3	5.59	6.62	3.26	3.39	1.7	4	3
4	1.05	.84	.47	.35	2.2	1	0
5	6.60	8.32	1.98	2.96	3.3	3	0
8	3.75	1.51	.71	.60	5.3	0	0
10	3.84	4.14	1.11	2.36	3.5	3	2
Av.	3.97	3.79 (95%)	1.29	1.53 (119%)	3.4	2.3	0.86

Results

Group A

The performances of the deafened *S*s (Group A) were, as Table VIII shows, highly variable. Five *S*s made no errors (false reports) in the check trials; one (A_6) made 1; two (A_1 and A_3) made 2 each; one (A_8) made 6; and one (A_4) made 9.

Of the five *S*s returning no false reports, three (A_2, A_5, and A_7) made 1, 0, and 2 collisions, respectively. Since these collisions were of the third type ('final-appraisal' collisions) and the performance ratios of these *S*s were high, being 3.8, 3.3, and 2.1, respectively, we conclude that they perceived and reacted to the obstacle. These *S*s possessed normal or superior hearing in one or both ears (see Table I). Since they were among those increasing the noise of their footsteps, we also conclude that they accomplished the perception, despite the blocking of their ears, by means of hearing.

The other two Ss making no false reports (A_9 and A_{10}) collided with the obstacle 13 and 11 times, respectively. Such large percentages of collisions (65 and 55) are hardly indicative of the 'obstacle sense.' We know from Experiment 5 that A_9 did not learn to perceive obstacles with his ears blocked; hence his results here must be accepted as the chance performances of an S lacking the ability. Since his results and those of A_{10} are so very similar in the present experiment, the conclusion that A_9 failed must be extended to A_{10}.

Of the remaining Ss in this group, two (A_3 with 16 collisions and 2 false reports, and A_4 with 9 collisions and 9 false reports) were classified with A_9 and A_{10} as demonstrating that they had failed to learn to perceive obstacles; and three, A_1, A_6, and A_8, were classified with A_2, A_5, and A_7 as having acquired that ability.

A_6 unquestionably belongs among the group demonstrating that ability. Not only are his collisions and false reports few in number (3 and 1, respectively), but his performance ratio (p/a = 5.7) is high and the standard deviations of his performances are exceptionally low being 15 percent of the means of his 'first perceptions' and 0 percent of the means of his 'final appraisals' - every one of which (17), measured to the nearest quarter-foot, were 0.25 ft from the obstacle.

The results of A_1 and A_8 are doubtful: A_1 made 2 false reports, A_8 made 6; A_1 collided with the obstacle 7 times, A_8, 6 times. Moreover, their performance ratios (both 1.8) are low, being next lowest A_9 who, as we know, failed to learn. These two Ss might well have been classified among the failures, but we preferred to err, if we erred at all, upon the side of inclusiveness. No harm would be done by that. If they should have been classified among the failures, that will be demonstrated in the next experiment in which cues that they might have been using in this one are eliminated.

Group B

The results of Group B (the hearing group), like those of the hearing group in Experiment 2, show clearly that the judgments of the Ss were based upon the obstacle (see Table VIII).

Four of the seven Ss (B_2, B_4, B_5, and B_8) made no errors in the check trials; one (B_1) made 1; one (B_{10}) made 2; and one (B_3) made 3. Their collisions varied in number from 0 to 4. One S (B_8), who made no false reports, made also no collisions; two Ss

(B_2 and B_4) made 1 collision each; two (B_5 and B_{10}) made 3 each; and two (B_1 and B_3) made 4 each. All of these collisions were of the third, the 'final-appraisal' type.

The performances of these *S*s did not suffer in any respect by the introduction of the check trials.

Summary and Conclusions

As these results show, all the *S*s tested from the hearing group (Group B) and certainly three (and perhaps five) of the *S*s from the deafened group (Group A) demonstrated that they had learned to perceive obstacles. Four (and perhaps six) of the *S*s from Group A who has met criterion in Experiment 5, failed to demonstrate that they based their judgments upon cues derived from the obstacle. One *S* (A_9) who did not meet criterion in Experiment 5, demonstrated again his inability to do so without hearing.

These results show again the necessity of conducting check trials in experiments of this kind. Except for them we should have had to conclude that nine instead of three (or possibly five) of the *S*s from the deafened group (Group A) had learned to perceive obstacles. Now that we know who did, we can again set conditions to determine what cues were used as the basis of their judgments.

Experiment 7

Experiment 7, a repetition of Experiment 4 with the deafened and hearing groups interchanged, was undertaken to determine how the *S*s reacted when temperature and olfactory cues were eliminated and auditory cues were enhanced by the reduction in the noise level of the experimental area - things accomplished by conducting the series at night.

The procedure was the same as that of Experiment 6 with the exception that the trials were conducted at night, between 8 and 10 p.m., instead of during the daylight hours. Six *S*s from each group served in the experiment - all from Group A who had given any indication in Experiment 6 that they had learned to perceive obstacles (we omitted only those clearly demonstrating failure) and all from Group B who were available.

Results

Group A

The results of Group A (the deafened group) are given in Table IX. False reports vary in number from 2 to 9 and collisions from 5 to 15. The *S* (A_1) returning the fewest false reports (2), collided

TABLE IX

RESULTS OF EXPERIMENT 7

Mean Distances and SD (in Ft) of the 'First Perceptions' and 'Final Appraisals,' the Ratios of These Distances, the Number of Collisions, and the Number of Times Obstacles Were Reported in the Check Trials.

Group A (blindfolded and deafened)

S	*p*		*a*		*p/a*	No. of collisions	No. of false reports
	M	*SD*	*M*	*SD*			
1	5.83	9.49	.75	1.00	7.8	15	2
2	10.65	9.50	4.20	6.47	2.5	5	9
5	4.90	8.40	2.78	2.88	1.8	12	5
6	3.40	6.08	.42	.33	8.1	11	3
7	4.02	5.24	1.40	1.66	2.9	12	4
8	9.50	8.98	5.50	5.90	1.7	11	9
Av.	6.38	7.95 (125%)	2.51	3.04 (121%)	4.1	11	5.3

Group B (blindfolded only)

S	*p*		*a*		*p/a*	No. of collisions	No. of false reports
	M	*SD*	*M*	*SD*			
1	6.38	4.21	1.76	1.96	3.6	3	1
2	2.93	4.34	1.24	1.98	2.4	5	1
4	3.00	1.42	.75	.48	4.0	0	0
5	7.47	1.94	3.63	.84	2.1	3	1
8	3.60	.94	1.27	.62	2.8	1	0
10	7.89	8.22	.68	.63	11.6	5	2
Av.	5.21	3.51 (67%)	1.55	1.08 (70%)	4.4	2.8	0.8

with the obstacle the greatest number of times (15); and the *S* (A_2) with the fewest collisions (5), returned the greatest number of false reports (9). There is little evidence here that any of the *S*s possessed the ability to perceive obstacles.

Group B

The results of Group B, in marked contrast to those of Group A, were better in this experiment than in Experiment 6. Although the number of collisions and false reports are approximately the same in the two experiments (see Tables VIII and IX), their performances were in every other respect much better. Their average performance ratios were increased to 4.4 from 3.4 and the average standard deviations of their 'first perceptions' fell from 95 percent to 67 percent of the average of the means and of their 'final appraisals' from 119 percent to 70 percent. The *S*s of Group B were more consistent and reliable in their performances in this experiment than in any other of this study.

Discussion and Conclusions

While the results of the hearing group (Group B) were expected - they conformed to those of the hearing group in Experiment 4 and to their own results in Experiment 6 - the results of the deafened group (Group A) were totally unexpected. The proportion of failures (100 percent) stands in disagreement with the results of the deafened *S*s in Experiment 4 in which four *S*s succeeded and two

failed, and in complete disagreement with their own results in Experiment 6 in which they all succeeded. Indeed, as will be recalled, they were selected to serve in this experiment upon the basis of their performances in Experiment 6. Because they increased the noise of their footsteps by shuffling their feet and clicking their shoes on the sidewalk, we concluded that their perceptions, in part at least, were still based upon sounds. We expected, therefore, when the trials were conducted at night and the intensive level of the ambient noises was greatly reduced, that the *S*s would better, not worsen, their performances. That they worsened them to the point of complete failure negates the conclusion that their perceptions were based upon sound and leads to the conclusion that their 'final perceptions' in Experiment 6 were based upon cues (thermal or olfactory) the elimination of which caused them to fail in Experiment 7. If this is the case, and we do not see how we can, in the light of our results, avoid accepting it, what then is the meaning of the deafened *S*s' attempts to increase the intensity of the sound of their footsteps? If some of the *S*s failed because of the lack of sound and others because of the lack of thermal or olfactory cues, what justification is there for the conclusion that any single condition is *necessary* for the perception?

In regard to the *S*s' attempts to increase the intensity of the sounds of their footsteps, the following observations may be pertinent. Failure in the trials (false reports, collisions, and low performance ratios) are chiefly matters of the 'final appraisals,' not 'first perceptions.' Of these two judgments, the 'final appraisals' are the more difficult. They are acquired later than the 'first perceptions' and their percentage of variability (standard deviation) from their means is usually greater (see all of the tables). When hearing is unimpaired, as it was in Part I, the *S*s of Group A based their judgments upon auditory cues - the most obvious and the most helpful - and learned rapidly. They met criterion in Experiment 1 and escaped the pitfalls of the check trials in Experiments 2 and 4. When the noise level of the experimental area was reduced in Experiment 4 by conducting the trials at night, their performances were greatly improved. When they were deafened in addition to being blindfolded in Experiment 5, they lost their ability immediately and completely, as Series 1, Table VII, shows. Audition was for them at that period a *necessary* condition. As the trials progressed, they did two things:

1. increased the intensity of the sound of their footsteps so as to break the barrier of their ear blocks; and

2. discovered other cues that were unnecessary when audition was available but were helpful when it was not.

(Just as a blinded person discovers other means than vision of per-

ceiving obstacles which were unnecessary when he could see.) By means of one or the other or of both of these methods, 9 of the 10 *S*s soon recovered their ability to meet criterion. One of the group (A_g), who had defective hearing in both ears at the higher audible ranges, was unable to accomplish this.

If the increased intensity of their footsteps was just sufficient to pass their ear blocks, the easier of the two judgments (the 'first perceptions') would suffer the less. The intensive increase might be sufficient for both judgments ('first perceptions' and 'final appraisals') for *S*s with particularly acute hearing or with ineffective ear blocks, but for most of them criterion would not be reached until the weak auditory cues of the 'final appraisals' were supplemented or replaced by thermal or olfactory cues, which are from their very nature perceived only when the obstacle (their source) is near.

If these assumptions are correct, then the results of Experiments 6 and 7 are readily explained. Of the *S*s (9) meeting criterion in Experiment 5, some (6) were able by the means described, to demonstrate that they perceived obstacles when check trials were introduced - their 'first perception' being based upon auditory cues and their 'final appraisals' upon thermal or olfactory cues. When the trials were conducted at night (Experiment 7) under conditions in which thermal and olfactory cues were lacking, the *S*s failed. They continued, however, to intensify the sound of their footsteps because those sounds were the cues of their 'first perceptions,' which they continued to make.

The results of the *S*s of Group B, Part I are very similar to those of Group A, Part II; the only discrepancy being the proportion of successes and failures in the experiments conducted at night in which *all* of the *S*s of Group A failed (Experiment 7), whereas two-thirds of those of Group B succeeded (Experiment 4). This difference may be explained upon the basis of the *S*s' acuity of hearing, the intensive increase in the sound of their footsteps, or the effectiveness of their ear blocks. If any or all of these factors were operative in an individual case, then *S* would be able to base his judgments upon auditory cues; hence his performances in the trials conducted at night, in which thermal and olfactory cues were eliminated and ambient noises were reduced, would either be unaffected or considerably bettered. Because the results of four of the *S*s of Group B were unaffected or considerably bettered in the night experiment (Experiment 4), we must assume that they, for one or another or all the reasons mentioned, were, in contradistinction to the *S*s of Group A, using auditory cues in the trials conducted at night.

Now for consideration of the conclusion that any condition is necessary for the perception. Since Diderot's formulation of the problem, search has been for the *necessary and sufficient condi-*

tions. The results of this study indicate, however, that the search is vain, that no single condition is *necessary* for the perception. Obstacles may be perceived without vision under many different conditions. Audition is the principal basis of the perception in the sense that it is the most reliable and accurate and most universal of the various cues; but blind or blindfolded people use, as we observed above, any and every cue that serves them: cutaneous pressures caused by deflections from the obstacle of the wind or even of their breath; thermal cues, warmths or colds, radiated from or interrupted by an obstacle; olfactory cues; or auditory cues.

Some of these cues are rarely present - few obstacles, for example, give off an odor but when they do, and when the observer has learned to associate the odor with the obstacle, 'final appraisals' are accurate and precise. None of these cues, on the other hand, is always present - not even audition. When none of them is present, as for example, in the case of the deaf-blind *S*s in the second Cornell study, the *S*s not only fail to perceive the obstacle but they resort to subterfuges to avoid collisions. If audition is eliminated, as it was for half of the deafened *S*s in Experiments 2 and 6, those failing to detect and to associate the available thermal and olfactory cues with the obstacle also failed to perceive the obstacle. If, however, they learned to base their judgments upon these cues, they succeed but only to fail in Experiments 4 and 7 in which these cues were eliminated.

The results of this study reconcile, to a great extent at least, the discrepant theories and conclusions of earlier investigators. Like the descriptions of an elephant given by the five blind men of India, every author is correct from his own point of view. Sounds, pressures, warmth, cold, and smell are under certain conditions *adequate* and *sufficient* for the perception of obstacles. None is, however, *necessary*, but audition is credited with being necessary because it is more often available than any of the others; and it is *necessary* in the sense that a totally deaf person will not be able to demonstrate the ability sufficiently often by means of the other cues, which are frequently lacking, to be credited with it.

SUMMARY AND CONCLUSIONS

This study was undertaken to determine whether the results and conclusions of experiments upon the perception of obstacles by blind and blindfolded *S*s, which were conducted indoors under carefully controlled laboratory conditions, could be duplicated out of doors under the uncontrolled conditions of everyday life; and to discover whether this perception was a special ability possessed by the gifted only or was one that was capable of being learned by every person possessing normal or near normal hearing. It was made with

20 undergraduate students (7 women and 13 men), who as audiometric tests revealed, varied normally for an unselected group in their ability to hear - some of them had normal hearing in one or both ears, some had acute hearing, and some deficient hearing, particularly at the higher audible ranges, in one or both ears.

The *S*s, matched for their ability to hear, were divided into two groups of 10 each. In Part I of the study, one group (Group A) was blindfolded only and the other (Group B) was blindfolded and deafened. In Part II, a repetition of Part I, the roles of the groups were interchanged. Group A was blindfolded and deafened and Group B was blindfolded only. Each group was, therefore, a control for itself as well as for each other.

The first experiments in each part of the study (that is, Experiments 1 and 5) were in learning. An endeavor was made in each to teach the *S*s to perceive the obstacle (a large masonite screen) under the particular conditions under which they were serving. The second experiments (Experiments 2 and 6) were test experiments with check trials (trials in which the obstacle was not present). They were undertaken to determine whether the *S*s had learned to perceive the obstacle in the first experiments - that is, to react to cues derived from the obstacle - or had merely met our criterion of learning (25 successful performances out of 30 trials - that is, 5 or fewer collisions) by chance or by limiting the distances they walked in approaching it. The third experiment (Experiment 3), a subsidiary conducted only in Part I, was undertaken to determine the role of odor in the perception. The procedure of Experiment 2 was repeated with *S*'s nostrils being so stopped that the possibility of detecting the obstacle by smell was eliminated.

All of these experiments were conducted during the day under highly variable conditions - ambient noises from near-by construction, street traffic, the passing of students to and from classes, and the heat and glare of the sun which varied with the cloudiness of the day. The last experiments in each part (Experiments 4 and 7) were conducted, therefore, at night under conditions that were much more constant: the noise level of the experimental area was considerably reduced and the cues, which owed their existence to the sun, were entirely eliminated.

The results of these experiments and the conclusions drawn from them are as follows.

1. *S*s possessing normal or near normal hearing, who were blindfolded only, learned rapidly to perceive obstacles under the complex and variable conditions met out of doors and demonstrated their ability in test experiments. Our results confirm those obtained indoors under laboratory conditions.

That all of these *S*s should have acquired the ability leads to the conclusion that it is not a special endowment possessed only by a few but is an ability that every normal person, possessing normal or near normal hearing, is able to acquire under the conditions of everyday life. The implications of this conclusion are far reaching: that all persons, blind but otherwise normal, are capable of learning to perceive obstacles; and that there is no reason, other than the lack of courage or the will to learn, for any of them leading a vegetative existence in which he has to be led about.

2. The behavior of the *S*s, who were deafened in addition to being blindfolded, was different from that of the *S*s who were blindfolded only.

The deafened *S*s increased the intensity of the sound of their footsteps. They made more noise than the group with unimpaired hearing and also more than they themselves made when their hearing was unimpaired. They did this, as we concluded, in an endeavor to break through the barrier of their ear blocks to obtain cues from hearing.

The deafened *S*s differed greatly among themselves in their performances: some learned nothing beyond the mere mechanics of the experiment; others learned at varying rates to meet criterion.

Those failing to meet criterion were divided, according to their audiometric records, into two groups: those possessing normal hearing; and those whose hearing was defective at the higher audible ranges. The failures of the *S*s, whose unimpaired hearing was normal, is due, as we believe, to the fact that they depended entirely upon auditory cues for their perceptions of the obstacle and the intensive increase in the sound of their footsteps was not sufficient to break through their ear blocks. The *S*s with defective hearing may have failed for the same reasons but it is also possible that they failed because their hearing was defective at the very ranges necessary for the auditory perception.

The *S*s meeting criterion also fall into one of two groups accordingly as their performances were bettered or worsened in the test experiments conducted at night.

The group, whose performances were bettered, found that they were still able when deafened - because of the increased intensity of their footsteps, or the acuity of their hearing, or ineffective ear blocks - to detect the obstacle by means of auditory cues, hence sought and utilized no others. We are forced to this conclusion by the very fact that their performances were improved in the night tests in which the noise level of the experimental area was reduced and all other cues except the auditory were eliminated.

The group, whose performances were worsened, sought other cues

when they found, after being deafened, that the increased intensity of the sound of their footsteps did not break through their ear blocks. they finally discovered the thermal and olfactory cues which, though less efficient than the auditory, served them well enough in the learning experiments to meet criterion and, in the daytime test, to demonstrate that they were reacting to cues derived from the obstacle. When, however these cues were eliminated in the night tests, they failed completely.

3. The fact that some of our *S*s failed to perceive the obstacle because of the lack of sound and others because of the lack of thermal or olfactory cues, leads us to conclude that no single condition is necessary for the perception. Obstacles may be perceived without vision under certain conditions by many different means - sound, temperature (cold and warmth), wind pressure, and odor. Audition is, however, the principal basis of the perception and it is *necessary* only in the sense that its cues are the most reliable, accurate, and universal of all the cues yielding the perception.

4. The course of learning for the *S*s with hearing is sudden or insightful; for those deafened there is a tendency for it to occur gradually as by trial and error.

5. The "black curtains" or "dark shades" reported by the hearing *S*s when they came near to the obstacle are imaginal experiences that are aroused associatively by auditory cues.

FOOTNOTES

1. Unlike auditory localization, the 'obstacle sense' is not dependent upon binaural stimulation. Monaural stimulation is as Supa, Cotzin, and Dallenbach found (see pp. 47-51) a sufficient condition which yields performances that are equal to those obtained with binaural stimulation.

2. The hearing loss was surprisingly less than that obtained indoors in the first Cornell Study by a similar method of impairment. In that study the loss was 65 dB at all frequency levels and the *S*s could not hear their footsteps nor understand speech unless shouted (see Supa, Cotzin, and Dallenbach, p. 36).

3. These results are much like those of the Cornell studies in which the 'final appraisals' were inches away from the obstacle.

4. Indeed some of the *S*s, because they had not been explicitly forbidden to do so, reached out and touched the board after making their 'final appraisal' to discover how far they were

away from it. These cases were counted as collisions. Although *S*s were told that they would be charged with a collision if they touched the obstacle, some were willing to suffer that dermit it return for the knowledge that they gained from it. Knowledge of results is an important factor in the acquisition of this ability.

5. As in the Cornell studies, *S* was permitted to walk toward the obstacle in any manner he wished. He could click his heels on the walk, shuffle his feet, and make as little or as much noise in walking as he wished. He could intensify noises normally made in walking, but 'artificial' noises, such as jingling coins or keys in his pockets, snapping his fingers, slapping his hands or thighs, whispering, hissing, whistling, and the like, were denied him. See Supa, Cotzin, and Dallenback, pp. 9 and 32-33.

6. Although A_9 was far from criterion in Experiment 5, he was included because he was willing and because we wished to discover how he would react in the check trials.

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